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Innovation and firm performance

R.G.M. Kemp

M. Folkeringa

J.P.J. de Jong

E.F.M. Wubben

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1 Introduction

Understanding the relation between innovation and performance in both large and small firms is relevant for researchers, policy-makers and managers of large and small companies alike. The topic of understanding innovations and their relationship with firm performance becomes even more relevant since the EU stated, in March 2000 in Lisbon, the ambition to become the world's most competitive and innovative region by 2010. The underlying rationale is that encouraging firms to innovate will lead to a better economic performance (Sirelli, 2000: 61); higher growth, more jobs and higher wages. Is this rationale empirically validated, and is there a preferential one-size-fits-all innovation trajectory for all European companies (large, medium and small)?

The objective of this research is to depict the current state of knowledge regarding the relation between innovation and performance in general, and for SMEs in particular. This research will therefore, first, emphasize the company size-related factors in innovation trajectories and firm performance (growth). Second, it will oversee relevant developments in models and techniques. Based on the literature, several models will be tested. To test a potential size effect, these models will be tested for all the firms in the sample, as well as for small and medium-sized firms separately.

The structure of the paper is as follows. In chapter 2, we describe the literature on innovation and firm performance. We discuss the relationship between innovation and performance by distinguishing the following stages: decision to innovate, innovation input, innovation process and innovation output. In chapter 3, the methodology and the measurement instrument will be discussed. In chapter 4, we present some first descriptive results and make a typology of the firms. In chapter 5, the innovation process and the relationship between innovation and firm performance will be tested. The closing chapter brings together some conclusions and discussions for further research.

2 Literature review

In this chapter, the literature on innovation and firm performance will be discussed. In section 2.1, two different research traditions are discussed; the economics-oriented tradition and the business-oriented tradition. In section 2.2, the changes in the economics-oriented research tradition are discussed. In this tradition, the innovation process itself becomes more and more the topic of research. This is studied by using firm-level data. Section 2.3 discusses the definitions and indicators that are used in the new approach. In section 2.4, the implications of the new approach for empirical research (models and estimation methods) are discussed. Finally, section 2.5 concludes this chapter.

2.1 Introduction

The literature covered by this paper fits the first of the two complementary traditions in innovation research (Brown & Eisenhardt, 1995, 343-378). That first and prevalent research tradition is economics-oriented. It traditionally examines both innovation patterns across countries and industries, and differences in the propensity of firms to innovate (Brown & Eisenhardt, 1995, 343; Dosi, 1988). However, in this research tradition the actual product development process remains a 'black box'.

The second research tradition, which is business-oriented, opens up that 'black box'. It examines how specific new products are developed, and indicates 'the organizational structures, roles and processes that are related to enhanced product development' (Brown & Eisenhardt, 1995, 375; Ancona & Caldwell, 1992). The entrepreneurs and the innovations are placed in the center of the analysis. This second tradition, in the terminology of the economics-based research tradition, discusses in essence the efficiency of the innovation trajectory; to what degree are innovative inputs transformed into innovative outputs? It splits up into three streams; the three streams take product development as (1) a rational plan, (2) a communication web and (3) problem solving, taking as objects of research, respectively, successful and failed products, project groups, and development projects. Well-known rational plan-researches are the Sappho-studies and the NewProd studies. Much of communication web-research starts from the work by Allen at MIT, and involves, e.g., Katz & Tushman (1981). Case-based research on the Japanese miracle by Imai, *et al.* (1985), and Takeuchi & Nonaka (1986), evolved into major MIT and Harvard research by, amongst others, Womack*, et. al*. (1990) taking the line that an innovation is about problem solving, as in the activities step model. The three streams of the second tradition are well established and, taken together, rich sources for further research. However, together they do not clarify the variety in innovation output and innovation performance, because the unit of analysis is mainly the project level. For the relation between innovation output and innovation performance the first economics-based research tradition is better suited. The unit of analysis in this tradition is the firm.

In Europe, in the economics-oriented research tradition, one witnesses an evolution towards evolutionary and learning perspectives (Arnold and Thuriaux, 2000: 9). In these perspectives, innovation becomes more interactive with more attention for incremental changes and knowledge creation. The advantage of this change is a better understanding of the selection mechanisms in innovations. The price to be paid is in the loss of generality. This paper is primarily in line with the economics-oriented first research tradition, because it's objective is to depict the current state of knowledge regarding the relation between innovation and performance in general. We try to incorporate parts of the second tradition by focussing on the innovation process (innovation inputs, transformation process and innovation output). We will have to see to what extent the evolution in research improves our understanding on the relation between innovation and performance and if the processes are different for small firms compared to medium-sized firms.

2.2 Fundamental changes in research

Since the 1980s one observes major changes in innovation research, namely the introduction of the Community Innovation Surveys (CIS), the process approach and the systems approach. Until then, innovation studies followed standardized practices.

Already in the 1950s innovation was discussed in technological and economic terms. On the one hand, there is an innovation when a product is successfully developed; on the other, a company, industry or country was considered to be innovative when there are substantial R&D funds. For long the sole indicators for innovativeness were the expenditures on R&D and the number of employees dedicated to R&D. As a result, based on the *Frascati*-manual of the OECD an impressive longitudinal dataset with various R&D statistics was built up, the so-called Basic Science and Technology Statistics. Thereby innovation research became path-dependent, emphasizing 'hard'ware and organisational entities. However, given the changing structure of the economy, towards a service economy, we learn more and more about a shrinking section of the economy (Arnold & Thuriaux, Technopolis, p.12). When evaluating innovations, business success was not considered to be a key issue (contrary to Schumpeter (1934); Voss (1994), 405-6), nor was the relation between the inputs (resources) and the output of the innovation process seriously questioned (Kleinknecht, 2000, 169-186). Innovation was presumed to be efficient. As a result, there were hardly any investigations into the quality of existing indicators and the potential of alternative indicators.

Starting in the 1980s, however, new indicators were developed by various researchers, but also by large institutes such as the OECD and, in particular, the European Commission. In 1992 a pilot study started the Community Innovation Surveys (CIS), which is based on the concept of national innovation systems (NIS). The CIS contains quantitative, dichotomous and polychotomous variables. The first EU harmonized survey, entitled CIS-1, was launched in 1993. CIS-2 was executed in 1996. In the autumn of 2001 CIS-3 started. The introduction and elaboration of CIS actually indicates a fundamental transformation of innovation research:

1 a process approach became prevalent;
2 a systems approach is introduced in (econometric) modelling;
3 new innovation indicators have been formulated and tested; and
4 the level of analysis.

Ad 1) For the CIS the EU took a process approach. The CIS brings a three-stage, firm-oriented dataset by distinguishing between the input, throughput and output stage of the innovation process (Klomp, 2001). As mentioned earlier standard R&D research was typically confined to the input factors of an innovation trajectory: the resources (financial, human) allocated to an innovation process. It was common to presume that R&D expenditures would lead to additional knowledge, and the dissemination of that knowledge base would result in innovations, especially products and processes. However, from a policy perspective, for several reasons additional insight into the innovation process became necessary (Arnold and Thuriaux, 2000). One of the reasons is to find out how to raise the effectiveness of innovation practices, be it via subsidies, enforcing collaborations, sector policies, or otherwise. Another reason is that R&D investments were questioned as the sole driver for innovations, strengthening the competitive position of businesses. The CIS presents a better balance of innovations by representing indicators from all the three stages of the innovation process. That is, it distinguishes between the input stage to the innovation process (e.g. R&D expenditures), the throughput stage (e.g. partner co-operation) and the output stage of the process (e.g. new products). First, there is the input to the innovation process of an industry or firm (e.g. R&D expenditures, people involved in innovation, subsidies); second, we have to distinguish the output of the industry or firm resulting (partly) from the innovation inputs (e.g. productivity, new products); third, when it comes to facilitating the operations of the firm, industry or economy, we call it the throughput character of innovations (e.g. cooperation, innovation in the mission statement). It turned out, for example, that the innovation output of Sweden and Finland was relatively low. That assessment was totally at odds with results from traditional research concentrating on R&D statistics, i.e. at the input stage (Klomp, 2001). The conclusion is that not all firms are equally efficient in turning research into sales or profits. Furthermore, firms may have different ways of innovating. Some firms rely on internal research while others may emphasize research networks (Mohnen & Dagenais, 2002: 4-5).

Ad 2) Another aspect of the new methodology of CIS is complex systems modelling. The systems approach acknowledges the complexity of the external and mutual influences on the innovation process. The traditional model assumes that innovation input influences the innovation process and the innovation process influences the innovation output. The systems approach is often understood as a traditional linear model, collapsing the three stages into one stage, e.g. test the determinants of innovation output. This reduced-form approach holds the risk of a simultaneity bias: e.g. the total sales may consist of new or improved products realised in an unbalanced way over the years (Klomp & Van Leeuwen, 1999: 5). Furthermore, input and output may be influenced by one and the same variable, e.g. technological opportunities or total sales. The impact of that third factor on the two interrelated factors should be estimated simultaneously. A final problematic aspect in modelling the relations in an innovation process is that the causalities are unclear, as with the chicken-and-egg problem: what was there first? The chain-link model of Kline and Rosenberg (1986) can be used to elaborate both unspecified feedback relations and unspecified causalities (Klomp & Van Leeuwen, 1999: 8). We shall come back to this model later on. We may conclude that the elaboration and application of the process approach and the systems approach together made it possible to take a more inductive approach towards the innovation process and its relation with firm performance.

Ad 3) New innovation indicators have been formulated and tested, especially in the CIS surveys. We elaborate on this in the next section.

Ad 4) A major advantage of CIS is that the data is available at firm level. Data from national statistics are typically at industry or national level. The CIS adopts the subject approach, i.e. the firm is the unit of observation. The alternative is an object approach, as used by patent counts and bibliometric counts of innovations. Such an object approach has the advantage that the firm is not bothered by the research, thereby lowering the response burden. On the other hand, it has the disadvantage that the data reveals no direct but derived information. The CIS data are direct data, i.e. information direct from the company.

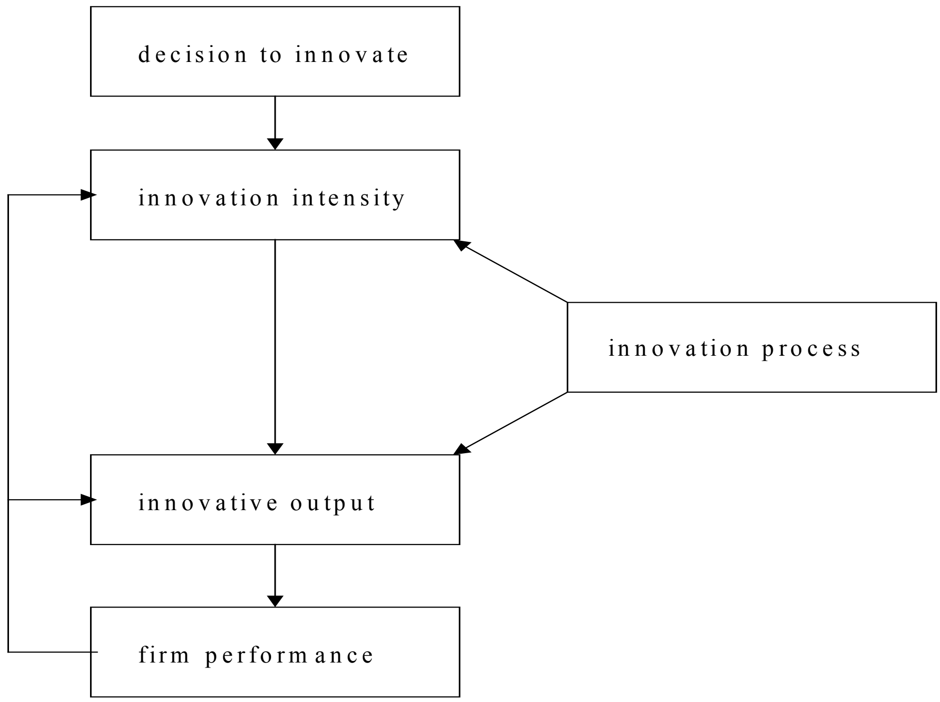
2.3 New innovation indicators

In this section, we define the different concepts and discuss how these concepts may be measured (e.g. innovative intensity, innovation output) and what aspects influence these concepts.

Nowadays one witnesses a proliferation of research on new definitions of innovation together with new innovation indicators. Many publications of recent date applied both the systems theory, the process approach, and related new indicators. Innovation indicators may be split up between macro, meso and micro level indicators on the one hand and between input, throughput and output indicators on the other hand, together providing nine cells of indicators (Broersma, 2001, 2). This study focuses on the micro level and distinguishes input, throughput and output indicators.

Much of the literature in the systems-theoretical approach uses models that incorporate at least four parts. These models are based on the Crepon, Duguet and Mairesse model (1998). First of all, there is a decision to innovate or not. Several aspects may influence this decision. Second, if a company decides to innovate, this influences the level of innovative input or the innovative intensity. In the next step, the innovative output is studied. In most studies, the innovation output is determined by the innovative input, i.e., the transformation of input into output (the throughput stage). Finally, the innovative output is related to the firm performance. This is visualized in figure 1.

figure 1 Research model



The innovation process may contain several feedback loops. Innovative output, via firm performance, may affect the innovation expenditures. The overall economic performance of a firm may affect all three stages of the innovation process of a firm. The growth of total sales may be higher for innovating firms than for non-innovating firms, etc. As a result of this interrelatedness of the relationships, the innovation process should be tested simultaneously.

2.3.1 *The decision to innovate*

Introduction

Prime in any innovation research should be to answer the question what factors influence the companies' intention and/or decision to innovate. Only once the question is answered positively, it is interesting to look at the process itself. Especially for small companies the split-up between those that are inclined to innovate and others that do not is particularly relevant.

The decision to innovate is an important decision for companies. A company can decide to be at the forefront of new development, decide to follow the new developments once they proved to be interesting or do nothing at all. Once the decision to innovate is made, the firm has to clear resources (financial and in time).

To distinguish innovative firms from non-innovative firms the sales of new or improved products (e.g. introduced the last three years) is often used (Mairesse and Mohnen, 2001, Klomp and Van Leeuwen, 1999). Alternatives used are direct questions such as 'does the firm innovate, yes or no?' or the time assigned to innovation (input side).

Factors influencing the decision to innovate

Several studies empirically test the propensity of firms to innovate. Felder, *et al.* (1996) used the Mannheim Innovation Panel to test the relation between R&D and other innovation expenditures. The data set contains a small firm subset containing firms with 5 up till 49 workers. The participation decision to innovate raises strongly with size. However, once innovating, the amounts invested as percentage of total sales is larger with small firms than with large firms. This is confirmed by Vossen & Nooteboom (1996). This effect is most pronounced for the total innovation expenditures. The relationship between firm size and R&D seems U-shaped. Vossen & Nooteboom conclude that small firms participate less in R&D, but at a greater intensity and with a greater productivity once they participate (Vossen & Nooteboom, 1996, 167). Also Kleinknecht (2000) and Kleinknecht and Mohnen (2002) found that the propensity to innovate is positively related with size although the relationship may not be linear and that among the innovators, smaller firms tend to have higher shares in sales of innovative products.

Lööf *et al.* (2001) used OECD and CIS data in their empirical work. Using a Cobb-Douglas production function they try to explain variation in productivity growth between the Nordic countries, using standard inputs (labour and capital) and the innovation investment variable, which substitutes the R&D variable. Using a Crépon, Duguet and Mairesse model (1998) they estimate the following four equations:
(1) firms' prosperity to innovate/decision to innovate;
(2) innovation inputs (innovation investment per worker);
(3) innovation output (log of innovation sales per worker); and
(4) productivity (sales per employee).

Throughput is not formally included in this set of equations. A two-step investment model is applied: First, the decision to engage in research must be taken (eq. 1); Next, conditional on engaging in research, the amount of investment must be decided upon (eq. 2). The decision to innovate is modelled as a Probit [0,1] model. To explain the propensity to innovate Lööf *et al.* (2001) use the following variables: firm size (employees), export intensity, prior patent applications, % non-R&D engineers, % administrators and several control variables. Firm size and patent applications are significant in all three countries, export intensity in two countries, the other variables in only one country. The control variables were not significant.

Technological opportunities, factor intensity and sector characteristics also influence the innovation decision (Lööf *et al.*, 2001). In a sector with high technological potentials, firms are more inclined to innovate. If they do not innovate, they may lose their market position. To estimate the effects of these variables, dummies were included in the regression, however, the results are not reported.

To summarize, the decision to innovate is an important decision for companies. Once a company decides to be active in innovation, the company has to dedicate resources to the innovation process. The decision is influenced by the size of the firm, the export intensity, prior R&D and characteristics of the employees (level of education). Also process characteristics such as the mission of the firm influence the innovation decision.

2.3.2 *Innovative intensity*

Conditional on engaging in innovations, the innovation intensity must be assessed. It concentrates on understanding the determinants that influence the level of resources dedicated to the innovation process. These resources are typical financial or human. The literature provides us with several indicators of the innovation intensity. Traditionally and still the most popular input indicator is the expenditures on R&D (Klomp and Van Leeuwen, 1999, Lööf *et al.*, 2001). The expenditures are often divided by total sales to come to the R&D intensity of a company. The R&D indicator is still further developed as an indicator. The main advantage of this indicator is that it is relatively easy to measure and collect. The extensive use of this indicator also improves the comparability of the different studies. However, several weaknesses can be mentioned (see Kleinknecht, 2000, for an extensive review). First, R&D expenditures are merely an input to the innovation process, but it states nothing on the results, or the efficiency. Second, R&D-related inputs make for a minority of innovation expenditures, varying from 25-50 percent. Third, R&D data tend to underestimate innovations in services. Finally, R&D questionnaires underestimate the small scale and often informal R&D activities in smaller companies. Complex questioning may result in such underestimation.

Several new definitions and improved R&D expenditures have been proposed. First, the 1992 Oslo-manual of the OECD posits a new definition of expenditures related to (technological) effort. It added to R&D expenditures six other cost categories, namely product/industrial design, trials, market analysis/introduction, training, patents and licensing, and innovation-related fixed asset investments (Felder *et al.*, 1996: 129; Klomp, 2001: 3). Vossen & Nooteboom (1996) claim that the relationship between firm size and the amounts of money allocated to innovations is most pronounced for total innovation expenditures. This innovation intensity variable was preceded by R&D intensity, denoting the (internal and external) R&D expenditures scaled by total sales. R&D and innovation expenditures are highly correlated (Mohnen & Dagenais, 2002, 13).

Total R&D expenditures, also called R&D investments, consist of internal R&D, external R&D and R&D in collaboration with universities and research institutes (Klomp & Van Leeuwen, 1999: 12). These three subsets together and respectively list the 'make, buy, or co-operate' alternatives to management decisions on innovation investments. Empirical results prove the importance of these distinct expenditures. It turns out that in a sample of 3,000 German industrial enterprises internal R&D covers slightly above 40 percent of total innovation expenditures (Felder, *et al.*, 1996: 130). This is supported by the CIS research, from where it is concluded that internal R&D amounts for less than 50 percent of the total innovation expenditures (Klomp, 2001: 3). When services are included a percentage even as low as 25 percent was arrived at (Kleinknecht, 2000: 3). This new indicator has as a downside that including non-R&D-items in the questionnaire lowers the response rates and lowers also the precision of answers. The reason is that many firms do not keep related records (Kleinknecht, 2000: 3).

Another traditional indicator is the number of employees dedicated to R&D. It is also easy to measure and is better suitable for services sectors. Also this indicator has several weaknesses, partly overlapping the weaknesses of R&D expenditures (e.g. no information on efficiency, minority of total expenditures). Furthermore, it does not include the quality of the employment input and the time devoted to innovation.

Mairesse and Mohnen (2001) take the share of new products in total sales as indicator for innovation intensity. It has the advantage that the final objectives of innovation trajectories are taken into account, i.e. extra turnover and/or profit. However, the share-in-sales variable is better used for output measurement. This will be further discussed below.

In this study, we use the number of employees dedicated to R&D as an indicator for innovative intensity. This indicator is improved by correcting for the average time the employees spent on innovation. This variable is also appropriate for small companies.

Factors influencing the innovative intensity

Several studies examined the factors that influence the innovation intensity. Innovation intensity is usually defined as the total of innovation expenditures divided by the total turnover of companies in a country or the number of employees dedicated to innovation. This dependent variable is modelled as a Tobit model, conditional on having decided to invest in innovations (Lööf, *et al.* 2001, p. 11). The literature provides us with several variables that influence the innovation intensity.

Lööf *et al.* (2001) include the same variables so as to explain the propensity to innovate (firm size (employees), export intensity, prior patent applications, % non-R&D engineers, % administrators and several control variables) plus obstacles to innovate, information for innovation, innovation strategies/innovation objectives, cooperation (domestic and foreign). The results are somewhat confusing at cross-country level. For example in Finland, firm size has a negative effect on innovation investment, in Norway the effect was positive and in Sweden the effect was not significant. Of the extra variables only the innovation objective extending the product range, information sources within the firm itself and customers and domestic cooperation with customers are significant and positively related with the innovation investment in all three countries.

Klomp en Van Leeuwen (1999) developed a simultaneous-equation model for the relationship between innovation and firm performance. They explained the innovation intensity by the following variables: prior total sales, prior cash flows, technological opportunities, age of the firm, subsidies, R&D on a permanent base, cooperation and innovation push and/or pull factors. There are feedback loops from the performance (development of the sales). They also include sector dummies and dummies for sector-size interactions. They test the model for all innovative firms and innovative firms with innovative output. They used a single-equation approach and the simultaneous approach. In the single-equation approach most of the variables proved to be significant, with the exception of push and pull factors. In the simultaneous-equation model prior cash flow, prior sales, development of sales and subsidies proved to be significant in various models.

In a study on the causality between R&D intensity and export intensity, Kleinknecht and Oostendorp (2002) proved that an increase in the export intensity of a firm significantly and positively influences the R&D intensity.

In a recent paper, Statistics Netherlands together with TNO detailed the input, throughput and output order of the innovation process for the Knowledge Based Economy (Klomp, *et al.*, 2002). The input stage consists of human capital (students, secondary vocational training, graduates finding a job, company-financed courses, and, finally, human resources in science and technology), next to the technological knowledge base of Dutch institutes (research institutes, universities, and private firms). The paper is descriptive in principle. The elaborate and multi-faceted concept seems promising but a shortage of data will make it hard to test it.

Innovation intensity can be seen as the effort a firm puts in innovation. It is often measured by the R&D expenditures divided by total sales or the number of employees dedicated to innovation. The innovation intensity is influenced by the firm size, export intensity, prior sales level or education of the employees, external support (subsidies) and innovation process characteristics.

2.3.3 *Innovation process*

The innovation process refers to the transformation process in an innovation trajectory. In most studies, the innovation process is modeled as influencing the innovative input and output. The process itself (e.g. cooperation in innovation projects) is not studied. Therefore, there is no separate equation to explain the innovation process in these studies. The process indicators are used to explain the effectiveness of the transformation process of innovative input to innovative outputs.

In the Eurostat-backed CIS the following throughput indicators are used: extramural/external R&D, co-operation and sources of information used for innovation. When it comes to sources of innovation 96 percent of all respondents refer to various sources within the industrial column, but it is dominated by sources within the firm. External advisors are referred to only by 52 percent of the respondents. Innovation centres are as popular with small companies (10<49 workers) as with larger firms. Publicly available sources are indicated by 79 percent, especially referring to conferences/journals and fairs and exhibitions. 24 percent of all innovating firms participate in joint co-operations. The small industrial companies, arriving at 18 percent, are the least interested. Extramural R&D amounts to almost 7 percent of total innovation expenditures, one-third of which goes abroad and one-third to universities and research institutes (Klomp and Van Leeuwen, 1999).

The evaluation of throughput may be evaluated along two lines of arguments: One line of argument is to concentrate on how expensive the innovation creation process is. Another line of argument is to emphasize how much is going on in this innovation creation process, the innovation efforts. Along the first line, throughput analysis functions as a measurement of efficiency of innovation processes: the ratio of innovation output and innovation input. The efficiency of the transformation of input into output can be enhanced by outsourcing part of the innovation activities, for example to universities or technological institutes. The innovation intensity variable may be used for this throughput evaluation by means of extramural R&D expenditures (cf. Klomp and Van Leeuwen, 1999). The disadvantage of this measure is that throughput remains no more than a closed black box. That is in contrast to the now prevalent views on the innovation process, which emphasise the enhancement of understanding of the integral innovation trajectories. Therefore, along the second line of argument, throughput is understood to detail the innovation creation process. As a consequence, one may focus on the internal and external orientations and relationships of the company. For example, is the company part of a larger network? Was innovation part of the company strategy?

An indicator of this second approach is the number of innovation projects. Subsidies as well as total innovation expenditures may be taken as an innovation input factor. Subsidies may also indicate an innovation throughput factor. In this case, innovation policies, and subsequent subsidies, are aimed at removing impediments in the functioning of the innovation system (Klomp, *et al.*, 2002, point 28). One means for removing impediments is to get companies involved in more general research projects, apart from joint ventures, co-makership agreements, etc. In the Netherlands we refer to STW projects. Another means is well-known, namely to subsidize the organisation via national or European institutes. Finally, a means of removing impediments is by offering support to firms, e.g. via management support, the provision of specific information, etc. In the Netherlands, Syntens amongst others brings to the organisation capabilities potentially useful in the process of innovation.

Klomp and Van Leeuwen (1999) included several dummies in their model to explain innovative intensity and innovative output that can be labelled as process indicators. They are subsidies, R&D on a permanent basis and innovation in partnership/cooperation. In this single-equation model, these variables significantly influence the innovation intensity. Permanent R&D has a positive effect on the innovative output, the other two variables show mixed results. In the simultaneous equation model, R&D on a permanent basis and cooperation has a significant positive effect on the innovative output.

Lööf *et al.* (2001) also include process-related variables in explaining the innovative intensity and the innovative output. They include five groups of process indicators: obstacles to innovate, strategy on innovation (innovation objectives), crucial sources of information for innovation, domestic and foreign cooperation in innovation. As discussed in the innovation-intensity section, only the innovation objective extending the product range, information sources within the firm itself and customers, and domestic cooperation with customers are significant and positively related with the innovation investment in all three countries (Finland, Norway and Sweden). For innovative output, none of the process indicators are significant for all three countries.

Kleinknecht and Oostendorp (2002) included the variable ‘Firm underwent a major restructuring’ in their model. The variable is significant in the equation explaining the propensity to innovate. In the R&D-intensity equation this variable is not significant. Although they did not define it as a process indicator, we think that it influences the innovation-transformation process and thereby is a process indicator because restructuring opens new opportunities and approaches for the firm. This will influence the efficiency of the innovation process.

Klomp, *et al.* (2002) see the throughput or process stage as knowledge diffusion. Prime is the stimulating effect of the government on the interactions between the universities and intermediaries, research institutes, and/or with firms. The same counts, c.p., for research institutes and intermediaries. Firms may have research contacts with forementioned parties but also with one another. This will stimulate the innovation efficiency. Summarizing, the innovation process refers to the efficiency of the transformation process of innovative input into innovative output. This efficiency is influenced by several aspects such as cooperation with other firms or universities, statements in the mission, knowledge about the customers and organizational change.

2.3.4 *Output indicators*

All the innovation input and innovation processes have to result in innovative output. The output of an innovation can take different forms. Most visible is a new or modified product. On the other hand, process innovations are also very important. These process innovations improve the transformation process, and they make the transformation process more efficient. This can have a direct effect on the profitability of a company. Most output indicators in empirical research are closely related with product innovations. Process-innovations outputs are less focused upon.

In empirical research, output indicators are in general referred to as new products and new processes, and resulting turnover. There seems to be a relationship between product and process innovations. Especially for manufacturing there is a high relation between the number of firms that introduce new products and firms that also introduce new processes (Klomp and Van Leeuwen, 1999). For services the innovation of a service cannot be disentangled from the innovation of the service process (De Jong *et al.*, 2002). In the Netherlands, in manufacturing, on average 25 percent of turnover in 1996 was the result of new or improved products. But small firms (20 to 49 workers) report on average no more than 15 percent. Statistics Netherland posits that the negative result of size is zero once we restrict ourselves to the subset of innovators (Klomp and Van Leeuwen, 1999, 31).

There are three main indicators for innovative output: innovative sales (as percentage of total sales), number of patents, and product announcements.
The share-in-sales indicator is an output indicator of recent date. The main advantage of this indicator is the direct link between the innovation effort and the commercial success. It explicitly focuses on the added value of innovation for a common objective of firms, that is growth. The share in turnover of products new to the firm or new to the industry is already part of the CIS. As a consequence the share-in-sales indicator is widely used in research (Mairesse and Mohnen, 2001; Klomp and Van Leeuwen, 1999). The advantage of this indicator is that efficiency of the research, both input and throughput, can be estimated (Kleinknecht, 2000). This indicator can also easily be adapted to service sectors. The main disadvantages are that a survey method is needed which may result in low (and possibly selective) response and comparison over sectors is problematic because of the diverse product life cycles between branches.

Patents are often used as an (intermediate) output indicator of innovation (Kleinknecht, 1996, 2000). The advantages are first the abundancy of publicly available information, with, second, the minor disturbances in these series. The relative importance of patents can be assessed by using citation analysis. In a survey, the number of patents can be easily asked. Problematic with this indicator is, first, the strategic use of patenting, which is meant to misguide a competitor. Second, many (service-related) innovations cannot be patented or are just not patented. Third, patenting will depend also on how high imitation costs are relative to innovation costs. Fourth, several findings suggest that 'time lead' and 'secrecy' are more important to appropriate innovation benefits than patent protection. Fifth, high-tech sectors tend to have a higher prospensity to patent. Sixth, several findings demonstrate that patent data underestimate, in terms of probabilities, the rate of small innovators (<10 workers) while overestimating the innovation intensity of those who innovate. We derive from this and related information that transaction costs are high for small firms that are first to patent. However, it turns out that once these small firms patent they apply for relatively higher numbers of patents.

The indicator product/service announcements from trade and technical journals is in practice since 1982 already (Kleinknecht, 1996, 2000). The announcements are typically based on trade and technical journals and are used in a series of studies on the relationship of firm size, market structure and innovation (for an overview, see Acs and Audretsch, 1993). From empirical tests it may be concluded that the innovation-output variable new product/service announcements adds insights to innovation research (Brouwer *et al.,* 1999). There are major advantages to this indicator (Kleinknecht, 2000, 7): First, it is also a direct measure of the innovation output. Second, it is cheap to collect, bypassing any non-response problem and privacy problems. Third, it is possible to split these data by type of innovation (differentiation, imitation, etc.), degree of complexity, etc. Fourth, data from small firms can also be covered easily. Fifth, a broad coverage of sectors (including services) and intersectoral flows can easily be realised. The first disadvantage with this indicator is the troublesome inter-country comparison. The number of (adequate) journals covered determine the number of innovations counted. Furthermore, the process innovations probably remain under-reported in such technical and trade journals. According to Kleinknecht (2000, 8) this is not such an issue. Finally, it may be difficult to combine this indicator with survey results.

Mohnen & Dagenais (2002) propose yet another innovation indicator, which is both constructed on the basis of and exploits the CIS-1 dataset. The authors propose as a new indicator the conditional expected share in sales of innovative products: 'Innovation is measured as the expected mean share of sales resulting from new or improved products conditional on the innovation input, the way innovation is organized, and some characteristics of the firm and its environment.' (Mohnen & Dagenais, 2002, 26). This composite indicator combines the estimated probability to innovate and the estimated percentage of sales resulting from new products. The indicator links up to the Mairesse and Mohnen (2001) paper. However, so far no more than a single test exists of this complex innovation indicator (Mohnen & Dagenais, 2002).

Evaluating the different measures of innovation output it seems that the share-in-sales of new products or services is an important indicator. It is present in recent empirical research of Mairesse and Mohnen (2001), Klomp and Van Leeuwen (1999), and in Lööf, *et al.* (2001). Kleinknecht (2000) uses the share-in-sales indicator for his innovation-intensity variable. Innovation output may be restricted to the first phase of the innovation trajectory, that is, the formalisation of a model or idea still to be tested. The number of patents may be an apt indicator. Such a restriction is useful for the distinction between output evaluation and performance evaluation. An innovation may also be pre-tested but not yet introduced at large scale in the market. An indicator of this situation may be new product announcements. In contrast, the share-in-sales indicator includes the total innovation trajectory, including the market introduction trajectory. In the end, an innovation is only successful if it is adopted by the market and results in sales for the company. Here also the externally oriented use of market intelligence and the systematic analysis of client satisfaction may be of additional explanatory relevancy. Kleinknecht (2000) concludes that the share-in-sales indicator is robust as innovation indicator, when compared to new product announcements. Klomp & Van Leeuwen (1999), as discussed earlier, take the log-odds ratio of innovative sales to total sales. In this study, we use the indicator percentage of new products/services (last three years) in turnover as output indicator.

Factors influencing innovative output

Innovative output is directly influenced by the innovative input and the innovation process. Several studies investigate this relationship. Klomp and Van Leeuwen (1999) hypothesise that the innovative output depends on the innovative intensity, three process variables (subsidies, R&D on a permanent basis and cooperation), push and pull factors, prior cash flow, sales, development of sales (feedback loop), technological opportunities, the age of the firm and some control variables (sector and size). In their simultaneous-equation model, the innovation-intensity is only significant at the 10% level. Of the process variables, R&D on a permanent basis and cooperation are significant (subsidies are only included in the innovation intensity equation). Furthermore, they conclude that the use of technological opportunities offered by customers, suppliers and competitors has a larger effect on the level of innovative output than the use of these opportunities offered by science (Klomp en Van Leeuwen, 1999: 61).

Lööf *et al.* (2001) found only a significant relationship between innovative input and innovative output in their Sweden sample. In the other two countries no significant relationship was found. Neither of their variables proved to be significant for all three countries. They argue that the model specification and the representativeness of the respondents may explain the mixed results.

Based on previous research, Kleinknecht and Mohnen (2002) concluded that several factors influence innovation. First of all, the share in sales of innovative products in total sales is not strongly related to size. Smaller firms have a lower probability to innovate, but once they innovate that share in sales is not lower than in larger firms. Second, demand enhances innovation (Schmookler effect) and innovation enhances demand, but the evidence is still inconclusive on the relative strength of causation in either direction. Third, there seems to be a difference between determinants of product and process innovation. Product innovation is stimulated by the following factors: (1) technological competition (percentage of innovators in one sector); (2) downward and horizontal knowledge sourcing, and the inverse of industry R&D spillovers; (3) diversification, laboratory research, innovation experience, and high capital intensity. In a similar vein process innovation is favoured by (1) firm size; (2) economic competition (various measures), foreign ownership and a recession; (3) upstream sources of knowledge and consortium research. Furthermore, the complementarity between product and process innovations is demonstrated by some researchers (e.g. Cabagnols and Le Bas, 2002). Cost-reduction strategies seem to stimulate joint process and product innovation over product innovation alone.

Summarizing, innovation output refers to the results of the innovation process. Innovation output is often measured by the percentage of sales from new products (e.g. three years old). Alternative measures are patents or product announcements. The innovation output is influenced by the innovative inputs and the innovation process.

2.3.5 *Firm performance*

In the end, all the innovative activities must result in better firm performance compared to companies that do not innovate. In measuring firm performance, different concepts are used. Most of the times, these firm- or economic-performance measures include: sales per employee, export per employee, growth rates of sales, total assets, total employment, operation profit ratio and return on investment (Sirilli, 2001).

Innovation-related factors influencing firm performance

In general, publications are positive about the effect of innovation on firm performance (profits and turnover).

A recent publication edited by Kleinknecht and Mohnen, and entitled *Innovation and firm performance. Econometric explorations of survey data* (2002), further adds drastically to the empirical knowledge on the innovation-performance relationship. It presents a series of 13 revised workshop papers, all using innovation survey data to explore 'a wide range of topics on innovation, from measurement issues to sources and effects of innovation' (Kleinknecht and Mohnen, 2002: xix). Most data are cross-sectional data from a single survey. Actually the number of papers on performance are restricted to five papers of which two papers on export performance. We will here detail the most relevant results (KM 02 xix-xxi).

Diederen *et al.* (2002: 81-83) conclude that innovative farmers show significantly higher profits and growth figures than firms that are not innovative. Also Favre *et al.* (2002) conclude there is a positive impact of innovations on profits. They take R&D intensity, market share, and concentration as the relevant causal factors. Also national R&D spillovers and, moreover, international R&D spillovers are positive for profits (Favre *et al.*, 2002, 218-9). Avanitis and Hollerstein (2002) conclude that the use of external knowledge, technological opportunity and the degree of innovativeness significantly increase the productivity of knowledge capital (Avanitis and Hollerstein, 2002, 246). The deliberate pursuit of certain objectives (e.g. creating a new market) and higher appropriability conditions raise the return to patents.

The two final papers in the volume examine the (causal) relationship between innovation and export performance. Levebvre and Levebvre (2002) try to find out how technological (R&D, level of automation, knowledge intensity, quality norms, unique know-how) and commercial capabilities (trademarks, networking, distribution access, manufacturing agents, and import activities) stimulate export. Kleinknecht and Oostendorp (2002) focus on the causal relationship between R&D and exports. They conclude that R&D intensity increases the probability of being an exporter, but it does not influence export intensity. On the other hand, export intensity influences R&D intensity. Also the higher share of higher educated personnel enhances both R&D and export performance.

In a publication based on the Dutch innovation monitor, Meinen (2001) is positive on the question whether innovation is worth doing. Firms executing R&D on a permanent basis, that co-operate with others and use various sources of information realise extra turnover of one percent point over 1996-1998. Permanent R&D raises the turnover by 8.5 percent, due to the new products. Co-operation would add an extra 2 percent point The use of information sources adds another 6 percent point. The process approach and the systems approach turned out to be useful tools to investigate such questions.

Lööf (2000) showed a positive relationship of innovative sales per employee (elasticity) on five different performance measurements (employment growth, value added per employee, sales per employee, operating profit per employee, and return on assets). The sales margin is not significantly influenced by innovative output. If a distinction is made between manufacturing and service firms, for service firms, the relationship between innovative output and employment growth is not significant anymore.
In another study, Lööf *et al.* (2001) tested the effect of different concepts on the productivity for three Nordic countries. Of the factors, innovation output, firm size, % non-R&D engineers, and % administrators are significant at the 5% level in at least two of the three countries. The elasticity of innovation output lies between 0.14 and 0.26. The other concepts are not significant at the 5% level in two or more countries.

In a preliminary study, Svandven and Smith (2000) showed that there was a lack between profitability and innovation. Thus while innovative firms may have higher rates of growth in terms of sales, employment, assets, productivity, etc. this does not show up in terms of profit. This lack of significance might be the result of the different context of the study. Different branches tend to have rather different rates of innovation, and since high innovation rates often need to be accompanied by high rates of investment, it is not a priori clear why there should be a link from innovation to profitability. Also taxation rules may explain the extent to which companies prioritise between profitability and growth (especially in an international context) (Arnold and Thuriaux, 2000: 11).

Finally, Klomp and Van Leeuwen (1999) used a simultaneous-equations model to test the relationship between innovation and firm performance. They measure firm performance in terms of firms' total sales growth and firms' employment growth. They hypothesise that the firms' total sales growth is dependent on the innovative output, size, industry dummies and the interaction term between the industry and size. For the firms' employment growth, also the firm's total sales growth is included. The firm's total sales growth is positively influenced by the innovative output, the firm's employment growth is not influenced by one of the variables in the equation.

Summarizing, studies show that firms that innovate have higher profits and grow faster. Especially innovation on a permanent basis, cooperation with other parties and the use of several information resources will result in extra turnover. Other studies failed to show an effect of innovation on profit.

2.4 Implications for the research model and estimation methods

2.4.1 *Implications for the research model*

From the literature review, it is clear that the process and systems approach is the most state of the art research approach. They bring forward serious advantages over older single regression modelling. It is based on the model of Kline and Rosenberg (1986) and Crépon, Duguet and Mairresse (1998). In these models, the innovation process breaks down in innovation input, innovation throughput and innovation output. Sometimes the innovation propensity and firm performance are included. These models take into account selectivity and simultaneity biases (see e.g Lööf *et al.*, 2001, Klomp en Van Leeuwen, 1999).

Another central point in the new approach is the feedback loop from economic performance to innovation performance. There can be feedback loops from firm performance to innovation input and/or innovation output. By using a simultaneous equation model, these feedback mechanisms can be tested.

Furthermore, the subject approach seems useful as it uses direct micro data from the companies themselves (e.g. innovation-related turnover) instead of derived information, as with the object approach (e.g. new product announcements). The subject approach also better serves the international comparability and new research areas such as the effect of organizational innovations and aspects of the knowledged-based economy (Archibugi and Sirilli, 2001).

In a recent paper the CBS together with TNO detailed the input, throughput, and output order of the innovation process for the Knowledge Based Economy (Klomp *et al.*, 2002). The <u>input stage</u> consists of human capital (students, secondary vocational training, graduates finding a job, company-financed courses, and, finally, human resources in science and technology), besides the technological knowledge base of Dutch institutes (research institutes, universities and private firms). The throughput stage is on knowledge diffusion. Prime is the stimulating effect of the government on the interactions between the universities and intermediaries, research institutes, and/or with firms. The same counts, c.p., for research institutes and intermediaries. Firms may have research contacts with forementioned parties but also with one another. The output stage consists of innovations and economic performance, besides the value added of partnerships (Klomp *et al.*, 2002). The paper is descriptive in nature. The elaborate and multi-faceted concept seems promising but a shortage of data will make it hard to test it. The subject approach enables it to include these multi-facet concepts.

2.4.2 *Implications for the estimation methods*

Recent studies have revealed a clear revolution as far as the estimation methods are concerned. As the reduced-form equations are no longer acceptable and feedback relations are to be expected, then Tobit, generalized Tobit, probit, and the Heckman model are becoming more and more standard practice. In the tests by Klomp & Van Leeuwen (1999) the log-odds of the ratio (P) of innovative sales to total sales is used. The log-odds is Ln(P/1-P). The advantage is that it makes it possible to infer from the estimates directly the impact on total sales and employment. Important here is, however, that this formula is in troubles with a 0 or 100 percent turnover share of innovative sales. That is, with new companies or non-innovative companies. Then, for instance, Tobit estimations should be used. Klomp and Van Leeuwen (1999) assume that the innovation input, the probability of innovation success and firm performance are jointly estimated (Klomp & Van Leeuwen, 1999, 55). As a result they estimate a simultaneous equation model with the method of Full Information Maximum Likelihood. The single-equations approach and the simultaneous-equation model show substantial differences. For example, the feedback loop starting from firm performance changes from the output stage to the input stage (Klomp & Van Leeuwen, 1999, 56-7).

Tobit is typically introduced to adapt for the conditionality of an equation on a certain decision, e.g. to innovate or not. One needs a Tobit analysis plus the imputation of values marginally different from the limits 0 and 1, to enable a re-estimation of the simultaneous model. In the papers analysed the generalized Tobit model is standard practice for establishing the propensity and intensity of innovations. In that model the actual level of an indicator is estimated as is the probability of observing a score between 0 and 1 (probit). The distribution of the disturbances can thus be established. In a neat modelling exercise the two disturbance terms do not differ significantly. Many researchers also use Heckman modelling for the simultaneous-equation modelling. Heckman (1979) allows to identify the parameters of the participation model and the intensity model separately (Felder *et al.*, 1996, 139).

Lööf *et al.* (2001) apply both 2SLS and 3 SLS. The 3SLS may bring in feedback effects from e.g. productivity (predictions) to innovation output. There is no clear direction in the resulting differences in significant factors.

We conclude that a wide range of estimation methods may be applicable: ‘Innovation survey data have peculiar characteristics, which require some special econometric techniques and invite us to be modest regarding the results obtained.’(Kleinknecht and Mohnen 2002: xxviii). First of all, the use of additional data sets is recommended as the number of explanatory variables may otherwise be rather limited. Second, the problem of selection bias is evident here. The (generalized) Tobit models may correct for that problem. Third, to correct for qualitative variables (ordinal, binary, or count data) the dependent-variable techniques are required. One may use the univariate probit model, the univariate logit model, the bivariate probit model, the trivariate probit model, the univariate probit model, count data models, and the multinominal logit model. Fourth, innovation survey data share the problem of simultaneity, e.g. between innovation, exports, investments, and R&D investments. Fifth, dynamic models and panel-data techniques typically cannot be applied as they require longitudinal data. 'Yet, after controlling for experience effects (lagged variables) and unobserved heterogeneity, the picture regarding determinants of innovation can be quite different. '(Kleinknecht and Mohnen 2002: xxviii)

Besides, we look at the differences between small and medium-sized firms as well. Several studies indicate that this distinction is worth to investigate because of differences between both types of firms (e.g. Meinen, 2001a; Klomp and Meinen, 2001a; Kleinknecht 2000).

2.5 Conclusions

We have come to the closing section of this chapter. It aimed at depicting the current state of knowledge regarding the relation between innovation and performance in general.

The research on innovations is rapidly developing. Due to political pressure and scientific advancement innovation research is transforming itself. The process approach, the systems approach and new indicators lead the research into new uncharted waters. But there is clearly a first-mover advantage for research on R&D data, and, to a minor degree, patent data. New innovation parameters have a hard time to prove their superiority. The backing of the Community Innovation Surveys by Eurostat clearly strengthens their position. The new indicators to stay are most probably the share in turnover of products new to the firm or new to the industry. Note that such a high share in sales of innovative products may be the result of the number of new products and/or the rapid diffusion of new products. Furthermore, the innovation-expenditures indicator will stay, although not all the underlying items may be included in the end. The reason is that the extra administrative burden on the firms may not countervene the added value of that extra information. For the others, e.g. information sources and technical innovations, additional testing will have to settle matters.

Although the new research trajectories may seem to be challenging one must be aware that the opening of the black box may not improve the explanatory power of the data. Many for small firms relevant observations have been made in the text. Additional details may bring more questions than answers for there is no foreseeable all-encompassing innovation-process standard and there is no end to further detailing. Is the price for extra insight in the innovation process a loss of generality? A new indicator already passed by is the one splitting up turnover data according to their vintage of innovation. It was introduced in the nineties as the shares in a firm's total sales that relate to products in different stages of the life cycle (Kleinknecht, 1996, 3). It is no longer in use.

In innovation studies, the 'linear model' and the neoclassical approach are left behind in favour of complex system models and entrepreneurship and knowledge creation at the centre of research. The methodologically based picture of the atomistic profit maximising firm is replaced by the learning entity with bounded rationality, developing external networks and internal capabilities working in a geographical space (Arnold and Thuriaux, 2000: 9). It is recommended to work on both Heckman, Tobit and probit methods. Also the Full Information Maximum Likelihood may be useful. They seem to be here to stay. Nevertheless, a major problem for our innovation research, as with other economic growth literature, is that there remains a huge gap between the formal models and the complex mechanisms tested in empirical work. Also the need to work often with indicators instead of factual data enlarges the problematic interpretation of empirical tests (Lööf *et al.*, 2001, 4).

In this chapter we have listed the prime developments in innovation research; we have listed the major publications that tested such new approaches, new methods and new innovation indicators. In the next section, we discuss the methodology of this research. In chapter 4 some first results are presented. In chapter 5, the model discussed in this chapter will be tested.

3 Methodology

The goal of this study is to test the relationship between innovation and firm performance. In this chapter we discuss the methodology of our study. In section 3.1 we discuss the research design, i.e. the background of the study, the sample and response. In section 3.2, we reveal our measurement instrument.

3.1 Research design

Background and response rate

In an empirical study, EIM has measured the innovativeness of Dutch companies. The study was carried out in the year 2000 and aimed at measuring the innovativeness of Dutch SMEs. In order to measure the innovativeness a telephone survey was carried out among 3,000 SMEs. In the survey the general director was interviewed or the person responsible for R&D and innovation. The sample for the study was stratified by applying a regional dimension. The Netherlands was split up in 15 regions and the study aimed at spreading the response equally over these regions, implying a net response of 200 companies per region.

In total, 13,759 companies were contacted by phone (see table 1). Of these companies, 2,144 companies did not meet our criteria (e.g. younger than three years, company liquidated, etc.). Of the 11,615 companies that did meet our criteria, 3,042 companies completed the questionnaire, a response rate of 26%. With 3,081 companies, an appointment was made for an interview. These appointments were not used because the target of a total number of 3,000 interviews was reached before the appointment. The rest of the contacted companies (5,492 companies) refused to cooperate or could not be reached (answering machine, busy, etc.).

table 1 Response rate

	Number of companies	*Percentage*
Contacted companies	13,759	
Companies that did not meet the criteria	2,144	
Number of companies	11,615	100
Completed questionnaires	3,042	26
Appointment	3,081	27
Refusals, answering machine, fax number, etc.	5,492	47

Source: EIM, 2002.

Composition of sample and net response

The dataset with 3,000 observations will form the basis for this study, containing innovation figures and economic performance data of the companies. In the following tables the composition of the respondents versus non-respondents of this dataset are demonstrated. In table 2 and table 3 a main distinction is made between industry, services and other sectors and three size classes. From the tables it can be learnt that the industry is slightly overrepresented in the response, other sectors are underrepresented. Companies with 1-100 employees are somewhat overrepresented as well. However, these differences are not significant; thus, we conclude that our response is representative for the composed sampling frame.

table 2 Response per sector (n=13,759)

	Respondents	*Non-respondents*	*Total*
	Percentage		
Industry	47.0	45.6	45.9
Services	43.8	43.7	43.7
Other sectors	9.2	10.8	10.4

Source: EIM, 2002.

table 3 Response per size (n=13,361)

	Respondents	*Non-respondents*	*Total*
	Percentage		
<10 employees	47.0	46.2	46.4
10-99 employees	47.3	48.3	47.5
≥100 employees	6.5	4.7	6.1

Source: EIM, 2002.

In table 4 a further distinction is made into the main sectoral activities of the companies and company size. We have mentioned the so-called SBI codes as well. These codes are used by Statistics Netherlands and the Dutch Chamber of Commerce to classify Dutch firms. We refer to Kamer van Koophandel (1997) for further details.

table 4 Industry and size characteristics of the sample (n=2.982)

Sector	*<10 employees*	*10-100 employees*	*≥100 employees*	*Total*
	Percentage			
Oil and chemical industry (SBI code 23, 24)	1.0	1.9	0.3	3.2
Electrotechnical industry (SBI codes 30-33)	1.4	3.0	0.3	4.6
Manufacturing of food (SBI codes 15, 16)	1.5	3.0	0.5	5.0
Metal industry (SBI codes 27, 28)	2.3	6.3	0.9	9.5
Other industries (SBI -codes 18-22)	6.5	7.6	0.9	15.1
Manufacturing others (SBI codes 25, 29, 34-36)	2.5	5.6	0.7	8.9
Financial and business services (SBI codes 65-67, 70-74)	16.1	7.6	0.2	23.8
Trade and hotel & catering (SBI codes 50-52, 55)	9.9	7.9	0.3	18.1

Sector	*<10 employees*	*10-100 employees*	*≥100 employees*	*Total*
Others	5.7	5.4	0.7	11.8
Total	47.0	48.3	4.7	100.0

Source: EIM, 2002.

3.2 Measurement instrument

In this section, we briefly discuss the measurement instrument used in this study. There are two groups of variables, innovation indicators (input, process and output) and performance indicators.

Innovation indicators

In order to measure the innovativeness of SMEs, a broad and more dimensional definition has been applied for this term. Innovations may occur on the input side, on the output side as well as in the process itself. A company can be highly innovative on the input side with R&D expenditures, a high share of employees involved in innovative activities, high expenditures on training and frequent use of subsidies, and at the same time show poor scores on process and output indicators. Other companies may show a high score in process indicators and poor scores on input and output indicators. This diversity in scores and the width of innovative activity within an organization are the most important reasons to measure innovativeness by making a distinction between innovative inputs, processes and innovative outputs (Prince *et al.*, 2000; Bernardt, 2000).[1] Within these three categories both 'hard' and 'soft' innovation indicators are taken into consideration. Innovative activities are much broader than the purely 'hard' technological improvements. Also 'soft' forms of innovative activities are relevant such as the procurement of software, expenditures on training, changes in organizational structure, customer satisfaction studies, etc. A great number in the total dataset consists of 'soft' indicators.

In table 5 the total of 24 hard and soft innovation indicators, which have been measured in the telephone survey, are presented[1]. One of the input indicators is aimed at the involvement in so-called STW projects. STW projects are cooperation projects that get subsidies.

[1] Not all of the indicators will be used in the regression later on. For instance, of the innovative output indicators the percentage of new products or services in total turnover is used and percentage of companies that possess patents is not used. We think that the former is a better and more direct measure for the innovative output; see also chapter 2. Some indicators will be combined in a new indicator.

table 5 Innovation indicators

INPUT
% Companies with special employees for innovative activities
% Employees involved in innovative activities
% Time spend on innovative activities
% Employees with masters or university degree
% Employees with training financed by own company
% Companies with relatively more advanced machinery and equipment
PROCESS
% Companies that made use of national innovation- and technology subsidies
% Companies that made use of European innovation- and technology subsidies
% Companies involved in STW projects
% Companies with continuous innovating as part of the company strategy
% Companies that have written down innovative plans
Number of automated company processes
% Companies in the possession of ISO certificate
% Companies in the possession of other formal quality certificate
% Companies with a change in the organizational structure in last 2 years
% Companies that measure customer satisfaction systematically
% Companies that performed or outsourced market research in last 2 years
% Companies that co-operate for innovation activities
Use of intermediary organization for information or advice
Outsourcing of innovative activities
OUTPUT
% Companies that possess patents
% Of new products or services in total turnover
% Companies with new products/services completely new for the industry
% Companies with new products/services completely new for the Netherlands
% Companies with new products/services completely new for Europe
Number of different innovative activities

Source: EIM, 2002.

Performance indicators

Beside these innovation indicators, also performance is measured. There are several definitions of performance, depending on the goals and context of the research. Performance is a multidimensional concept. The following performance indicators have been measured in this study:

- total number of employees and the development of this number in the 1998-2000 period (in a qualitative and quantitative manner);
- turnover (in Dutch guilders) and its development from 1997 to 1999 (qualitative and in percentages);

– export share in total turnover and its development from 1997 to 1999 (qualitative and in percentages),
– net profits/losses in 1999 and 1997 (qualitative and in guilders) and the development (qualitative).

In this chapter, we discussed briefly the empirical setting of this study. We discussed the research design, the response and the measurement instrument. In the next chapter we discuss some first results.

4 First results

Before focussing on the relationship between innovativeness and performance, at a glance some first results will be provided to get an idea of the innovative activities of the firms in our sample and their relative importance. The results will be of a descriptive nature. In section 4.1 the innovative activities for the whole sample are presented. In section 4.2 four groups are constructed with a cluster analysis. For these four groups, the performance indicators are presented.

4.1 Innovative activities

The firms in our sample perform a wide range of innovative activities. The improvements of current products or services and of the own production process are mentioned most frequently as innovative activities, with respective percentages of 81 and 80 (see table 6).

table 6 Innovative activities (n=2,996)

Innovative activities	*Percentages of respondents*
Improvement of current products or services	81
Improvement of production process	80
Development of new products or services	65
Training of personnel	63
Improvement of logistical processes	51
Other activities	12

Source: EIM, 2002.

About two-thirds of the companies are involved in the development of new products or services. In order to get an idea of the real innovative character of these products and services some questions were asked about their newness. From table 7 it appears that 16% of all respondents consider their newly developed products or services to be completely new to the sector, 14% of all respondents consider them to be new for the Netherlands and 10% for Europe. More often newly developed products or services are only partly new for the sector (mentioned by 23% of all respondents), for the Netherlands (19%) or Europe (14%).

table 7 Newness of products and services (n=2,999)

Newness	*Percentage of respondents*
Completely new for the sector	16
Completely new for the Netherlands	14
Completely new for Europe	10
Partly new for the sector	23
Partly new for the Netherlands	19
Partly new for Europe	14

Source: EIM, 2002.

Sector-specific activities

Breaking down the innovative activities per sector, it appears that the development of new products and services is above average in the oil and chemical industry and in the manufacturing of food (see table 8). Perhaps not surprisingly the percentage is highest for the category business services aimed at R&D and ICT-development. The food industry and to a less extent also the metal industry focus their innovative activities on the production process. The electrotechnical industry concentrates innovative efforts more at improving current products or services.

table 8 Type of innovative activities per sector (in %)

	Improvement of products or services	*Development of new products or services*	*Improvement of production process*	*Training of personnel*	*Improvement of logistical processes*
Oil and chemical industry (SBI codes 23, 24)	86	78	81	69	50
Electrotechnical industry (SBI codes 30-33)	85	71	75	70	54
Manufacturing of food (SBI codes 15, 16)	88	79	90	67	57
Metal industry (SBI codes 27, 28)	76	57	84	78	54
Other industries (SBI codes 18-22)	77	55	81	54	50
Manufacturing others (SBI codes 25, 29, 34-36)	85	71	80	66	51
Financial and business services (SBI codes 65-67, 70-74)	84	72	77	56	45
Trade and hotel & catering (SBI codes 50-52, 55)	79	59	80	59	59
Others	77	55	77	63	48
Total	81	65	80	63	51

Source: EIM, 2002.

Size-specific innovative activities

A similar analysis can be made for the three size classes (see table 9). For all innovative activities it can be concluded that there is a positive relationship between the percentage of innovating companies and their size. Larger companies are more active in innovation than smaller companies. The difference between small and larger companies is most evident with respect to the training of personnel. Less than half of the companies with less than 10 employees mention this as an innovative activity of their company. The corresponding percentage for companies with 100 or more employees is 90.

table 9 Type of innovative activities per size (in %)

	Improvement of products or services	Development of new products or services	Improvement of production process	Training of personnel	Improvement of logistical processes
0-10 employees	75	61	71	42	40
10-100 employees	87	67	88	82	60
≥100 employees	93	78	93	90	78
Total	81	65	80	63	51

Source: EIM, 2002.

4.2 A typology of innovative firms

In the previous section it appeared that differences in innovativeness occur between various industrial sectors and firm sizes. For the purpose of our study it is interesting to investigate if various groups of firms can be distinguished according to their degree of innovativeness. This is based on the fact that the companies are no homogeneous mass, but very diverse with respect to their innovative inputs, processes and outputs.

Three-step analysis

By means of cluster analysis, we have developed a typology of innovative firms. We performed a three-step analysis. First, we identified which variables to include in the cluster analysis. Care must be exercised in the selection of the variables used; the addition of irrelevant variables can have a serious effect on cluster recovery (Milligan and Cooper, 1987). On the other hand, the selected variables should be representative for the typology we want to present (Everitt, 1993). Therefore, we have chosen to use all 26 indicators from our data in the cluster analysis. This enabled us to identify groups of innovative firms that are homogeneous on innovative inputs, processes and outputs. To reduce the risk of including irrelevant (non-discriminative) variables we first performed a principal component analysis using PRINCALS. This technique is developed especially for non-metric variables such as in our data. We followed the usual procedure by summarizing the data in two components (Gifi 1990; Van de Geer, 1988).

The second step consisted of a hierarchical cluster analysis. In a cluster analysis companies are grouped in such a manner that the differences in scores on the indicators in one single cluster are as small as possible (the group of companies is as homogeneous as possible with respect to their scores on the indicators), and the difference between companies from the various clusters is as big as possible. In this way, more or less homogeneous clusters or segments may result that are very different from each other. Milligan and Cooper (1987) point out that several hundreds of clustering methods are in existence. Ward's method is generally considered to be an excellent clustering algorithm. We refer to Milligan and Cooper (1987) for a detailed discussion on various clustering methods and their applicability in various situations. They conclude that Ward's method generally provides excellent cluster recovery, therefore we used this method to come up with an initial typology of innovative firms.

To discover the most optimal solution, our final step consisted of k-means cluster analyses and the assessment of internal and external validity. K-means cluster analysis is a so-called ‘non-hierarchical’ method. It is a clustering method in which the cases (companies) are divided into clusters based on their distance to initial starting points. Some k-means methods use randomly selected starting positions, but we employed the cluster means of our Ward’s clustering for this purpose. Generally, this method provides more stable and better cluster solutions (Milligan and Sokol 1980; Punj and Stewart 1983). In the end, a solution with four groups of innovative firms appeared to best interpretable. Besides, this solution proved to have a high internal and external validity (see below).

Four types of innovative firms

By means of cluster analysis we have identified four groups of innovative firms:
- output-oriented companies (14% of the sample),
- allround companies (19%),
- process-oriented companies (33%) and
- lagging behind companies (34%).

In table 10 the most important characteristics of each type are summarized.

table 10 Four types of innovative firms briefly characterised

Output-oriented companies ✓ focus on output innovations ✓ highly educated personnel ✓ many employees involved in innovative activities ✓ continuously innovating is often incorporated in the strategy ✓ below-average process innovations ✓ many new products/services ✓ high turnover from new products/services	Allround companies ✓ allround innovators ✓ many company trainings ✓ high use of subsidies ✓ innovative in all parts of the organization ✓ dynamic organisation structure ✓ frequent co-operation and outsourcing of innovative activities ✓ many patents ✓ considerable level of new products/services
Process-oriented companies ✓ focus on process innovations ✓ a low level of innovative activities ✓ many trainings ✓ below-average innovation outputs ✓ many different types of innovative activities	Companies lagging behind ✓ hardly innovative ✓ below-average scores on almost every indicator ✓ lowest level of automation ✓ hardly no use of subsidies ✓ hardly no process innovations ✓ below-average innovative outputs

Source: EIM, 2002.

Internal validity

In table 11, the four types of innovative firms are described and compared in more detail. For every indicator a summary score is presented. Milligan and Cooper (1987) mention that the internal validity is a minimum condition to prove the quality of a typology based on cluster analysis. The clusters should differ significantly on the variables that we used to identify the various firm types. We performed a ONEWAY analysis of variance to test for significant differences. It appeared that each variable showed significant differences on at least one of the groups ($p<0,01$). Therefore, we conclude that the internal validity of the typology is very good.

table 11 Comparison of the four types of innovative firms on innovation indicators

Indicator	*Output-oriented*	*All-round*	*Process-oriented*	*Lagging behind*	*All firms*
INPUT					
% Companies with special employees for innovative activities	100	100	100	85	95
% Employees involved in innovative activities	73	43	43	61	54
% Time spent on innovative activities	31	30	20	13	21
% Employees with masters or university degree	41	29	19	27	27
% Employees with training financed by own company	15	29	27	13	21
% Companies with relatively more advanced machinery and equipment	41	53	37	18	34
PROCESS					
% Companies that made use of national innovation- and technology subsidies	33	56	23	2	24
% Companies that made use of European innovation- and technology subsidies	4	17	6	1	6
% Companies involved in STW projects	1	6	1	0	2
% Companies with continuous innovating as part of the company strategy	92	98	83	45	74
% Companies that have written down innovative activities	48	89	78	17	55
Number of automated company processes	5.6	7.1	6.4	3.6	5
% Companies in the possession of ISO certificate	1	36	32	2	18
% Companies in the possession of other formal certificate	13	39	42	13	27
% Companies with a change in the organisational structure in last 2 years	35	71	58	18	44
% Companies that measure customer satisfaction systematically	27	54	49	15	35
% Companies that performed or outsourced market research in last 2 years	36	58	40	12	34
% Companies that co-operate for innovation activities	64	88	74	33	62
% Companies that use an intermediary organization	72	67	51	31	50
% Companies that outsource innovative activities	26	52	37	12	30
OUTPUT					
% Companies that ever applied for a patent	33	42	16	5	19
% Of new products or services in total turnover	37	25	10	9	18
% Companies with new products/services completely new for the industry	55	35	1	2	16
% Companies with new products/services completely new for the Netherlands	53	35	0	0	14
% Companies with new products/services completely new for Europe	40	23	0	0	10
Number of different innovative activities	3.5	4.5	4.1	2.4	3.5

Source: EIM, 2002.

External validity

For a further description of the firm types, the clusters can be compared on economic performance indicators. This is presented in table 12. It appears that large differences can be observed in the economic performance of the various clusters.

First, the various types of companies differ significantly in company size. Allround companies and process-oriented companies are generally much larger than output-oriented and ‘lagging behind’ companies. This explains a number of differences we found in table. It can be expected that smaller companies have not much to gain with process innovations, so it is not surprising that smaller firms are present very often in the output-oriented and 'lagging behind' firm types. For instance, these firms have lower scores on measuring customer satisfaction systematically. It is likely that smaller firms have less resources available for formal research activities and do not consider this of much added value. Besides, due to their smallness most workers will be in direct contact with customers. This makes formal research less evident.

Milligan and Cooper (1987) discuss the concept of external validity as another way to assess the quality of a cluster typology. Assuming a positive relationship between innovativeness and economic performance, the external validity of our typology seems quite satisfying. It appears that firms that are innovative in some way (output-oriented, allround or process-oriented) achieve better results in terms of turnover growth, employment growth and profit improvement. The 'lagging behind' firms perform worst on the indicators in table 12 that measure growth, but it is remarkable that they perform better on profit as a percentage of turnover. These companies may feel no need to employ innovative activities due to a satisfying economic performance. Because investments in innovation are lacking, their profit margins are probably better. Another possible explanation is that these firms may already have innovated in the past, so that current innovative activities are not necessary.

table 12 Comparison of the four types of innovative firms on performance indicators*

	Output-oriented	*Allround*	*Process-oriented*	*Lagging behind*	*All firms*
Number of employees (mean)	8	29	26	7	17
Number of employees (median)	4	20	18	3	9
% Turnover growth during past three years	35	32	22	15	23
Turnover per employee (€)*	119,000	152,000	142,000	116,000	131,000
% Employment growth during past three years	0.8	2.9	2.0	0.4	1.4
% Companies reporting profit improvement in past three years	55	52	52	50	52
Profit as a percentage of turnover*	5	5	5	8	6

* *Before calculating these scores, outliers were removed from the analysis. We excluded every case that deviated more than three standard deviations from the mean score.*

Source: EIM, 2002.

Summarising, output-oriented firms are particularly directed towards innovative output, as is witnessed by an above-average percentage in turnover of new products or services. As relatively small companies, this type demonstrates an above-average growth of turnover. Profit share in turnover, however, is below-average indicating that the focus of these companies on innovative output does not directly lead to a payback in higher profits. Moreover, their focus on many innovative activities seems to require relatively high investments. Although the percentage of companies reporting profit improvement is slightly above average, it can be concluded that a relatively high turnover from new products/services does not yield above-average profits in the short run.

In comparison with the output-oriented firms, allround firms also show high scores on input and process innovation indicators. Allround companies may be viewed as the next stage of output-oriented companies. They are bigger in size and have enlarged their innovative scope. However, it is difficult to conclude if such a grown-up attitude is favourable or not. The enlarged focus might lead to efficiency advantages in the production process, but the bigger size is responsible for a higher overhead as well.

In contrast with output-oriented and allround firms, process-oriented firms primarily focus on process innovations. Despite the attention for process innovation the profit level (as a percentage of turnover) is not above average.

Firms lagging behind are relatively less innovative than the other clusters of firms. Poor scores on practically all innovation indicators, however, do not seem to be a problem for performing economically well at the time of our research. However, the growth of turnover, employment and profit indicates that these companies might have problems in the longer run. The question is to what extent these companies can maintain their current profitability in times of economic recession.

5 Relations between innovation input, output and firm performance

In this chapter various econometric models are estimated in order to find determinants of innovation inputs, innovation outputs and firm performance. Our focus is on small and medium-sized enterprises (SMEs). Most studies focus on medium-sized and large companies and use size as a control variable. Our data set allows us to focus on small and medium-sized firms and do separate analysis for small firms and medium-sized firms.

Analyses are generally carried out in threefold. Firstly, models are estimated at the level of all available firms in the dataset. Secondly and thirdly, the same model specifications are used to determine coefficients for the samples of small firms and medium firms separately. Following Dutch definitions, a small firm is defined as a firm with less than 100 employees. Medium firms have a number of employees that lies between 10 and 99. For completeness, large firms consist of 100 employees or more. The number of observations involving large firms in the dataset is too small, so large firms are left out of the analysis.

In the following section, the operationalization of variables is described in detail. A distinction is made between innovation input, process and output variables as determinants of innovative input, output and firm performance. In this study, we do not explain the innovative process. The process variables are only used to explain the transformation from innovative input into innovative output. In the next sections, the econometric models are presented, following the approach of Klomp and Van Leeuwen (1999). Compared to this study, the added value of our analysis consists of the different size classes and the availability of a large number of different variables. Sections 5.2 and 5.3 deal with the determinants of innovation input and output, respectively. The chapter is closed with a concluding section.

5.1 Operationalization of variables

The used dataset contains a large number of different innovation indicators and firm performance variables. Table 13 presents the selected variables for regression analysis in section 5.2 and further[1]. For each variable a description is given, as well as the scale and, in case of categorical variables, the value assigned to each category. The innovation-related variables can be grouped into three categories, innovation-input variables, innovation-process variables and innovation-output variables.

Concerning the innovation-input variables, we selected three variables from the dataset for our analysis. We define the *innovation intensity* as the share of total time all employees spend on innovative activities within a firm. Furthermore we use information on education (current education level and courses financed by company) as innovation-input variables. These last two variables are only used as innovative input variables to

[1] Some variables that are presented in table 5 are not used in the regression or combined to a new variable.

explain the innovative output. They are not used as indicator for the innovative intensity of the firm. The input variable advanced machinery is not included in the regressions. Although it can be seen as an input variable, it is not often used in the literature.

A lot of innovation-process variables are available in our dataset. The firm strategy is regarded important (*continuous innovation*, *innovation written down*), as well as the possession of certificates. Subsidies (national and European) are also part of the process[1]. Activities as the systematical measurement of customer satisfaction and market research also may influence the innovative activities of a firm. A dummy variable is included, indicating whether a firm uses the services of an intermediary organisation, which aims to assist entrepreneurs with issues that relate to innovation. We included two extra variables for the direction of the innovation activities. A distinction can be made between firms that focus on product innovation, and firms that focus on process innovation. Firms were asked if their primary innovation goal is process or product innovation. This may affect the nature of their innovative activities as well as the level of innovative sales. Co-operation variables are included, distinguishing between co-operation with other firms, research institutes and universities. The process variables number of automated company processes and the outsourcing of innovative activities are excluded. As *innovation-output* indicator, we use the share of new products and/or services in total turnover. We have a number of other innovation-output indicators at our disposal, such as the application for patents, the number of innovative activities and 'newness of the product', but we assume that the effect of these variables is incorporated in the *innovation-output* indicator. Hence, we only use the innovation-output indicator *share of new products in total turnover* for analysis. *Turnover*, *turnover growth* and *export growth* are used as firm-performance indicators. For *turnover* we applied a logarithm transformation. *Turnover growth* and *export growth* are percentual changes between 1997 and 1999. Furthermore, dummy variables indicating a loss or a profit in 1999 are included.

[1] Subsidies can also been seen as innovative input because they can be part as a financial input. STW projects are not used as variable in the regression because only a very small part of the companies are involved in these projects.

table 13 Variable characteristics

Variable	*Description*	*Scale*	*Operationalization*	*Missing (total observations: 2,999)*
Innovation input variables				
innovation intensity	% total time employees spend on innovative activities	metric		524
degree education	% employees with masters or university degree	metric		53
courses	% employees with training financed by own company	metric		none
Innovation input variables				
nat. subs	use of national innovation and technology subsidies	dichotomous	0 = no subsidy 1 = use of subsidy	none
Eur. subs	use of European innovation and technology subsidies	dichotomous	0 = no subsidy 1 = use of subsidy	none
cont. innovation	continuous innovating as part of the company strategy	dichotomous	0 = no 1 = yes	none
innov. written down	written down innovative activities	dichotomous	0 = no 1 = yes	none
certificate	in possession of certificate	ordinal	0 = no 1 = attempting to get certificate 2 = yes	none
change organization	change in organizational structure in last 2 years	dichotomous	0 = no 1 = yes	none
customer satisfaction	systematical measurement or customer satisfaction	dichotomous	0 = no 1 = yes	none
market research	performing of outsourced market research in last 2 years	dichotomous	0 = no 1 = yes	none
intermediate	customer of intermediate organization	dichotomous	0 = no 1 = yes	none
product innovation	innovation goal is product innovation	dichotomous	0 = no 1 = yes	3
process innovation	innovation goal is process innovation	dichotomous	0 = no 1 = yes	3
co-op other firms	co-operation with other companies	dichotomous	0 = no 1 = yes	124
co-op research inst.	co-operation with research institutes	dichotomous	0 = no 1 = yes	124
co-op educational inst.	co-operation with educational institutes	dichotomous	0 = no 1 = yes	124
Innovation output variables				
innovation output	% new products/services in total turnover	metric		971

Variable	Description	Scale	Operationalization	Missing (total observations: 2,999)
Firm performance variables				
log turnover	logarithm of total turnover 1999	metric		27
turnover growth	% change in total turnover between 1997 and 1999	metric		437
export growth	change in share of export in total turnover between 1997 and 1999	metric		374
profit development	profit development indication in period 1997-1999	ordinal	-1 = decreased 0 = same level 1 = increased	282
loss99	dummy indicating loss in 1999	dichotomous	0 = no loss 1 = loss	none
profit99	dummy indicating profit in 1999	dichotomous	0 = no profit 1 = profit	none

Source: EIM, 2002.

For each firm the sector is available at a 2 digit-level (see Kamer van Koophandel, 1997). The companies are grouped in five major sectors, *manufacturing*, *construction, trade*, *hotel&catering&transport* and *services*. For these variables, *effects coding* is used (see Hair *et al.*, 1995: 110). *Construction* is chosen as comparison group and coefficients for other sector variables represent differences for any group from the mean of all groups.

In Annex 1 the correlation matrix of all variables is displayed.

For some variables, missing values form a serious problem. This is especially the case for *innovation output*, the share of new products/services in total turnover. For nearly one third of all companies, *innovation output* is not observed. Other variables that have relatively many missing values are *innovation intensity*, and the firm-performance variables *turnover growth*, *export growth* and *profit development*.

Using the variables from table 13, we construct a number of hypotheses prior to analysis. In table 14, expected signs of the relations between explanatory variables and innovation input and innovation output are displayed. Dependent variables are *innovation intensity* and *innovation output*. We expect a positive influence of the subsidy variables on innovation intensity and innovation output. Capital injections for innovative purposes should enhance the possibilities to increase innovative activities, for instance-hiring personnel or creating facilities.

For some process variables, the effect is more difficult to forecast. In general, positive effects may be expected from innovation-process variables on both innovation input as well as innovation output. However, the signs of the possession of certificates and a change in organizational structure are not clear beforehand. Certificates could restrict firms in their acting, firms with certificates are expected to be less flexible. On the other hand, the innovation process may be more formalized resulting in more efficient innovation processes. A change in organizational structure could be associated with cuts in innovative investments, resulting in less innovative input and perhaps also less innovative output. On the other hand, such a change can improve the flexibility of a firm,

leading to more innovative activities. Finally, it could be well possible that a number of firms concentrate merely on innovation processes, rather than on innovative output. When firms primarily focus on enhancing innovative processes, they are expected to have lower innovative sales. The dependent variable *innovation output* does not reflect the outcome of improving processes.
Our major hypothesis concerns the effect of firm performance on innovative activities. The expected influence of turnover growth, export growth and profit on innovation input and output are positive. Larger turnovers and profits should create more space for innovative activities. Export growth implies more competition from foreign companies. In order to compete with these firms, innovative activities should be increased. The dummy variable indicating a loss should of course display a negative sign. For size (measured as the logarithm of turnover), the expected sign is not clear beforehand.

table 14 Expected signs of effects on innovation input and output

	Dependent variable	
Variable	*Innovation input*	*Innovation output*
Innovation-input variables		
innovation intensity	n.a.	+
degree education	n.a.	+
courses	n.a.	-/+
Innovation-process variables		
nat. subs	+	+
Eur. subs	+	+
cont innovation	+	+
innov written down	+	+
certificate	n.a.	-/+
change organization	-/+	-/+
customer satisfaction	+	+
market research	+	+
intermediate	+	+
product innovation	+	+
process innovation	+	-
co-op other firms	+	+
co-op research inst.	+	+
co-op educational inst.	+	+
Innovation-output variables		
innovation output	n.a.	n.a.
Firm-performance variables		
log turnover	-/+	-/+
turnover growth	+	+
export growth	+	+
profit development	+	+
loss	-	-
profit	+	+

Source: EIM, 2002.

5.2 Determinants of innovation input

The first part of our analysis aims at finding determinants of innovation input. The variable of interest is *innovation intensity*, the total amount of time all employees spend on innovative activities, as a percentage of total available time[1]. The whole set of innovation and firm-performance variables, including the sectoral dummies, are used as explanatory variables in the innovation equation. With y_i denoting *innovation intensity* for firm *i* and x_{ij} the value of explanatory variable *j* for firm *i*, this equation reads:

$$(1) \qquad y_i = \alpha + \sum_{j=1}^{J} \beta_j x_{ij} + \varepsilon_i \quad ,$$

with $\varepsilon_i \sim N(0,\sigma^2)$. The explanatory variables that are included in the model are displayed in table 14, for which an expected sign is filled. The sectoral dummies are added in the model. A constant term α is included. Equation (1) could have been modelled as a Tobit model, which takes account of zero shares of innovation input. However, the number of observed firms for which this is the case, is relatively small (167 firms). The standard linear-regression model seems most appropriate to model the innovation-input equation, using ordinary least squares (OLS) as estimation method.

Table 15 presents the estimation results of the innovation-input equation. First, we comment on the results of the sample of all small and medium firms. We have excluded large firms (≥100 employees), to obtain unbiased estimates towards SMEs. Of a total of 2,999 observations, 1,769 firms are left for which all included explanatory variables have a non-missing value. This is mainly caused by *innovation intensity*, which is not observed for nearly 500 firms and the exclusion of large firms.

table 15 Estimation results innovation input model

	All SMEs		*Small firms*		*Medium firms*	
	Coefficient	*T-value*	*Coefficient*	*T-value*	*Coefficient*	*T-value*
Constant	56.46***	13.5	58.97***	8.3	13.89**	2.1
Nat. subs.	2.05**	2.1	5.73***	3.0	0.83	0.9
Eur. subs.	1.20	0.8	1.77	0.5	2.04	1.5
Cont innov.	4.07***	3.8	4.54***	2.7	2.66**	2.3
Innov. written down	1.04	1.2	2.08	1.5	-0.74	-0.8
Change organization	-1.07	-1.3	-.084	-0.6	0.07	0.1
Customer satisfaction	0.27	0.3	-0.24	-0.2	0.71	0.9
Market research	2.32***	2.7	3.02**	2.1	1.34	1.5
Intermediate	1.29	1.5	3.47**	2.4	-1.34	-1.6
Product innov.	1.19**	2.5	1.44*	1.8	0.90*	1.8
Process innov.	-1.61	-1.6	-2.83*	-1.8	1.29	1.1
Co-op. other firms	2.17***	2.7	2.19	1.6	1.13	1.4
Co-op. research inst.	2.58**	2.5	4.57**	2.3	1.14	1.2

[1] The innovative inputs degree education and courses are not used as dependent variables. They focus on the quality of the input and not the level of input which is the relevant aspect in this research.

	All SMEs		Small firms		Medium firms	
	Coefficient	*T-value*	*Coefficient*	*T-value*	*Coefficient*	*T-value*
co-op. universities	-0.04	0.0	0.03	0.0	0.03	0.0
Turnover (log)	-7.66***	-12.8	-8.35***	-7.6	-1.17	-1.3
Turnover growth	0.00	1.1	0.01	0.8	0.01	0.8
Export growth	0.13**	2.5	0.22***	2.9	-0.02	-0.3
Profit development	-0.12	-0.3	-0.01	0.0	-0.14	-0.3
Dummy loss 99	3.17**	2.0	3.96	1.6	2.38	1.4
Dummy profit 99	-1.15	-1.1	-0.16	-0.1	-1.65	-1.4
Dummy industry	0.08	0.1	0.61	0.4	-0.07	-0.1
Dummy trade	1.98**	2.0	2.10	1.2	1.37	1.4
Dummy hotel, transport	0.41	0.3	1.06	0.4	0.26	0.2
Dummy services	2.26**	2.4	2.17	1.4	2.38**	2.4
Number of firms	1,769		907		862	
R^2	0.20		0.21		0.09	
F value	F (23,1745) = 18.9***		F (23,883) = 10.16***		F (23,838) = 3.52***	

**p< .10, **p<.05, ***p<.01.*

Source: EIM, 2002.

In the equation with all SMEs included, 12 of the 24 variables are significant. Among these variables are the use of national subsidies, continuous innovation in the mission, market research, product innovation, export growth and cooperation with other firms. These variables all have a positive effect, as expected. The turnover has a negative effect on the innovation input. This implies that if turnover increases, innovation input decreases.

When splitting up the sample in small and medium sized firms, different results come to the fore. The independent variables in the regression model explain the innovation intensity fairly well for the sample of small firms. However, for medium firms, none of the coefficients are significant at the 1%-level. For small firms, obtaining national subsidies has a significant positive effect on the amount of time put into innovation. European subsidies have no discernible effect on the innovation intensity.

Firms that incorporate innovating activities in their long-term strategies spend relatively more time on innovation. This can be seen as a structural process. This holds for both small and medium firms, displaying a larger effect for small firms. Writing down this innovative strategy has no significant effect on innovation input. A change in the organizational structure of the firm and the measurement of customer satisfaction also display no discernible influences. In contrast, carrying out market research leads to increased innovation intensity. Again, the effect is only significant for small firms. Small companies that have contacts with the intermediate organization have significantly higher innovation inputs than firms without the contacts. Co-operation with other firms and research institutes has a positive effect on innovation input for the sample of all firms, but when the distinction is made between small and medium firms, only the coefficient of co-operation with research institutes holds its significance for small firms.

Larger firms, in terms of the logarithm of total turnover, spend relatively less time on innovative activities. Looking at the two different size classes, this only holds for small firms. Apparently, medium firms form a homogeneous group where firm size does not matter for the amount of time put into innovation. Turnover growth has no significant effect on innovation input. However, a larger mutation of export share (in total turnover) leads to increased innovation intensity. This effect is again only observable for the sample of small firms.

Based on the presented results, one may conclude that size does influence the relationship between several explanatory variables and the innovation input. Especially for small firms, several variables have a positive impact on the innovation output. National subsidies, contacts with the intermediary organization, the cooperation with research institutes and the growth in export intensity influence the innovation input. For medium-sized firms, it is not so clear what contributes to the innovation input. Variance in the individual explanatory variables does not significantly explain the variance in the innovation input (except for continuous innovation and product innovation, the latter only at the 10% level).

We also estimated the linear models for the sample of firms that have innovative sales. In this approach, firms with a zero share of new products or services in total turnover are excluded. Since innovative activities do not have to result in innovative output (e.g. process innovation), different results may be obtained for the two different samples. The estimation results for the sample of firms with positive innovative sales are displayed in table 16. The results do not differ considerably from the sample of all small and medium firms as previously discussed. There are a few notable differences though. For all firms with innovative sales, the execution of market research only has a positive effect on the innovation input at the 10% level. Product innovation is not significant anymore. For small firms, the significance of the coefficients related to market research and being a customer of the intermediate organization disappears for the sample of firms with innovative sales. This indicates that market research has no influence on innovation intensities of output-oriented firms. Furthermore, for small firms the positive influence of co-operation with other firms and research institutes is more apparent. For medium-sized firms, only European subsidies and continuous innovation have a positive effect on the innovation input (at the 10% level).

table 16 Estimation results innovative input model, firms with innovative output

	All SMEs		*Small firms*		*Medium firms*	
	Coefficient	*T-value*	*Coefficient*	*T-value*	*Coefficient*	*T-value*
Constant	58.58^{***}	9.5	63.55^{***}	5.6	5.54	0.6
Nat. subs.	2.30^{*}	1.9	5.84^{**}	2.5	0.77	0.7
EUR. subs.	0.89	0.4	-.087	-0.2	2.96^{*}	1.7
Cont innov.	5.61^{***}	3.4	6.95^{***}	2.7	3.23^{*}	1.8
Innov. written down	0.62	0.5	2.67	1.4	-2.08	-1.5
Change organization	-1.26	-1.2	-1.30	-0.7	0.33	0.3
Customer satisfaction	0.81	0.8	-0.34	-0.2	1.27	1.2
Market research	1.87^{*}	1.7	2.76	1.4	0.89	0.8
Intermediate	0.78	0.7	2.67	1.3	-0.99	-0.9
Product innov.	0.35^{**}	0.5	-0.44	-0.3	0.87	1.0

	All SMEs		Small firms		Medium firms	
	Coefficient	*T-value*	*Coefficient*	*T-value*	*Coefficient*	*T-value*
Process innov.	-0.94	-0.7	-2.14	-1.0	1.79	1.2
Co-op. other firms	3.32***	3.1	3.67**	2.0	1.52	1.4
Co-op. research inst.	3.60***	2.7	5.77**	2.2	1.89	1.6
Co-op. universities	-0.70	-0.6	-.031	-0.1	-0.97	-0.9
Turnover (log)	-7.86***	-9.4	-9.06***	-5.5	0.09	0.1
Turnover growth	0.01	0.7	0.01	0.6	0.01	0.9
Export growth	0.14**	2.2	0.23**	2.4	-0.03	-0.5
Profit development	0.10	0.2	-0.07	-0.1	0.07	0.1
Dummy loss 99	1.58	0.7	0.03	0.0	4.14*	1.8
Dummy profit 99	-2.96**	-2.1	-2.45	-1.1	-2.18	-1.4
Dummy industry	0.15	0.1	1.06	0.4	-0.30	-0.2
Dummy trade	2.16	1.4	2.28	0.8	1.19	0.8
Dummy hotel, transport	0.59	0.3	0.94	0.2	-0.02	0.0
Dummy services	3.11**	2.1	3.11	1.2	2.98*	1.9
Number of firms	1,107		539		568	
R^2	0.21		0.21		0.11	
F value	F (23,1083) = 12.17***		F (23,515) = 6.07***		F (23,544) = 2.83***	

*p< .10, **p<.05, ***p<.01.*

Source: EIM, 2002.

5.3 Determinants of innovation output

Our next focus is on innovation output. We use the share of new products or services in total turnover as innovation-output indicator and dependent variable. Since a number of firms have zero innovative output, simply estimating a linear regression model by OLS leads to biased estimates. Tobit models are better suited to model such a dependent variable (Greene, 2000; Franses and Paap, 2001). We consider two types of Tobit models, named type-1 Tobit model and type-2 Tobit model (Amemiya, 1985). For the type-1 Tobit model, a latent variable y_i* is introduced. It takes a value of 0 if firms have no innovative output, and 1 if firms have innovative output. This latent variable is used in the model as follows:

$$(2) \qquad y_i = \begin{cases} \alpha + \sum_{j=1}^{J} \beta_j x_{ij} + \varepsilon_i & \text{if } y_i^* = \alpha + \sum_{j=1}^{J} \beta_j x_{ij} + \varepsilon_i > 0 \\ 0 & \text{if } y_i^* = \alpha + \sum_{j=1}^{J} \beta_j x_{ij} + \varepsilon_i \le 0 \end{cases},$$

with ε_i ~ N(0,σ^2), and the matrix *X* containing all explanatory input, process, output and other variables from table 14. The model can be estimated using Maximum Likelihood (ML). The type-2 Tobit model is a special case of the standard Tobit model. It consists of two different models, a Probit model and a standard linear-regression model. In the Probit part of the model, a binary dependent variable is considered, which takes a value of 1 if a firm has innovative sales (0 if firm has no innovative sales). Conditional on having innovative sales, the share of innovative sales in total turnover can be modeled using a standard linear regression model ('the OLS part'). The type-2 Tobit model reads as follows:

$$(3) \qquad y_i = \begin{cases} \alpha + \sum_{j=1}^{J} \beta_j x_{ij} + \varepsilon_{2i} & \text{if } y_i^* = \alpha + \sum_{j=1}^{J} \beta_j x_{ij} + \varepsilon_{1i} > 0 \\ 0 & \text{if } y_i^* = \alpha + \sum_{j=1}^{J} \beta_j x_{ij} + \varepsilon_{1i} \leq 0 \end{cases},$$

with ε_{1i} ~ N(0,1) and ε_{2i} ~ N(0,σ_2^2). The model can be estimated using ML. However, a simpler method can be applied, known as the Heckman two step-procedure (Heckman, 1976). In the first step, the Probit model is estimated with ML. In the second step, the linear regression model is estimated (using OLS) for the firms with a positive share of innovative sales. In the OLS- part, the inverse Mills ratio (or 'Heckman-term') is added to the standard regression model, correcting for the bias in the estimates. This produces less efficient estimates than ML, but in general estimation results will not differ substantially. We shall use the Heckman two step-procedure in our analysis.

All in all, the type-2 Tobit model has an advantage over the type-1 Tobit model, in that it can model two different effects. In the Probit part, the influence of explanatory variables is measured on the decision to have innovative sales or not. In the OLS part of the model, the effect of explanatory variables on the *size* of innovative output can be estimated, conditional on having innovative sales.

Results type-1 Tobit model

The estimation results of the type-1 Tobit model are presented in table 17. The explanatory variables displayed in table 14 are used for the innovation output equation. Innovative output rises when employees invest more time in innovative actions. This effect is larger for medium companies than for small firms, because of scale advantages. These effects are all highly significant. Firms that invest in the education of their employees have lower innovation output. For small and medium-sized firms separately, this effect is only significant at the 10% level. These courses may have a negative effect on the employee's creativity. More general methods and procedures will be used as a result of training. Furthermore, training has a larger influence on innovation processes, rather than innovation output. National subsidies significantly contribute to the innovation output, although for the two groups separately, the effect disappears. Firms with a continuous focus on innovation as part of their strategy and with product innovation as goal also seem to have higher innovative sales. Effects are larger for small firms than for medium firms. Medium firms often have a wider range of products or services, some of which have no relation with innovation. Small firms can be highly dependent on one or two product categories (specialization). For all firms, certificates have a negative effect on the innovative output. This is especially true for medium-sized firms. Companies in possession of a certificate are less flexible and are restricted by rules and procedures in order to keep the certificate. A second explanation is the certificate's value for customers. For customers, the possession of a certificate often is a sign of quality. Thus a certificate enhances market power. Once in possession of a certificate, less effort has to be made to attract customers with innovative products or services. For all SMEs, there is a significant effect of changes in the organization on innovative output. This effect disappears if the SMEs are split up in small en medium-sized firms.

Looking at the link between innovation output and firm performance, we can conclude that turnover growth and export growth have a significant positive effect on innovative sales. Effects are comparable for small and medium enterprises. In general, no significant effects from the co-operation variables and dummy variables can be distinguished.

table 17 Estimation results innovation output model, type-1 Tobit model

	All SMEs		*Small firms*		*Medium firms*	
	Coefficient	*T-value*	*Coefficient*	*T-value*	*Coefficient*	*T-value*
Constant	22.06**	2.5	7.07	.05	34.15***	2.6
Innov. intensity	0.43***	10.2	0.38***	6.3	0.55***	8.3
Degree education	0.05*	1.9	0.04	1.1	0.07	1.5
Courses financed by firm	-0.07**	-2.4	-0.08*	-1.9	-0.06*	-1.8
Nat. subs.	3.76**	2.2	4.94	1.5	2.73	1.6
Eur. subs.	-5.35*	-1.9	-7.96	-1.3	-3.37	-1.3
Cont innovation	8.23***	4.0	10.07***	3.0	5.76**	2.4
Innov. written down	1.45	0.9	0.13	0.0	3.46*	1.8
Certificate	-3.56***	-2.9	-3.10	-1.4	-2.83**	-2.2
Change organization	3.27**	2.2	4.13	1.6	2.58	1.6
Customer satisfaction	2.86*	1.9	3.61	1.4	2.63*	1.7
Market research	0.25	0.2	-1.47	-0.6	2.14	1.3
Intermediate	-2.09	-1.4	-4.04	-1.5	-0.82	-0.5
Product innov.	8.00***	8.4	8.62***	5.5	7.17***	6.7
Process innov.	-0.77	-0.4	-1.62	-0.6	0.36	0.2
Co-op. other firms	1.42	1.0	1.23	0.5	0.68	0.4
Co-op. research inst.	0.45	0.2	5.10	1.4	-2.16	-1.2
Co-op. universities	0.82	0.5	4.15	1.4	-1.94	-1.2
Turnover (log)	-2.16*	-1.8	-0.09	0.0	-3.77**	-2.1
Turnover growth	0.04***	4.0	0.05***	3.0	0.04***	2.9
Export growth	0.28***	3.1	0.28**	2.0	0.23**	2.1
Profit development	0.64	0.8	1.75	1.2	-0.19	-0.2
Dummy loss 99	2.63	0.9	6.85	1.5	-2.74	-0.8
Dummy profit 99	-0.04	0.0	1.55	0.5	-2.56	-1.1
Dummy industry	0.83	0.5	1.62	0.5	0.69	0.4
Dummy trade	2.43	1.2	2.93	0.9	2.34	1.1
Dummy hotel, transport	5.51*	1.9	3.53	0.6	5.82**	2.0
Dummy services	2.10	1.1	3.95	1.2	-0.16	-0.1
Number of firms	1,418		719		699	
R^2	0.26		0.26		0.26	

*p< .10, **p<.05, ***p<.01.

Source: EIM, 2002.

Results type-2 Tobit model

Next, we use a type-2 Tobit model to explain the level of innovation output, conditional on having innovative sales. The estimation results are displayed in table 18. The probit part explains the aspects that influence the decision to have innovative sales, the OLS part the extent that the different aspects contribute to the level of innovative output. The inverse mills ratio (sometimes called Heckman term) is insignificant for all specifications, indicating we have a two-part model, with no bias in the estimation of the OLS part of the model.

For all firms, the decision to have innovative output is positively influenced by continuous innovation, a change in the organization structure, the measurement of customer satisfaction, product innovation as innovation goal and the turnover. Contacts with the intermediate organization have a significant and negative effect on the decision to have innovative output. This in contrast to our expectations.

The extent of innovative output is positively influenced by the innovative intensity, national subsidies, continuous innovation, change in the organization, the growth in turnover and the growth in export. Courses financed by the firm, certificates and the turnover have a negative effect on the level of innovative output. The effect of courses and certificates is the same as in the previous analysis. Courses and certificates seem to have a negative effect on creativity and the flexibility necessary for innovation. For turnover there is a positive effect on the decision to have innovative output (the larger the firm measured in turnover, the more they decided to have innovative output) and a negative relationship with the level of innovative output (the larger the firm, the lower the percentage of innovative output). This confirms the findings of Van Vossen and Nooteboom (1996) that if a small firm decides to have innovative output, they are more innovative than larger firms.

Effects for small and medium-sized firms separately are very similar. The variables *continuous innovation*, *change in organization, customer satisfaction* and *product innovation* all have a significant positive effect on the probability on having innovative sales. For small firms, *turnover* (log) has a significant positive effect on the probability on having innovative sales. The variable *Contacts with intermediate organization* has a significant negative effect. For medium-sized firms the variables *innovation intensity* and *innovation written down* also have a significant positive effect on the probability on having innovative sales, *cooperation with research institutes* has a negative effect.

Most of the variables that influence the probability on having innovative sales do not affect the level of innovative output significantly. The level of innovative output for both small and medium-sized is positively influence by innovation intensity and turnover growth. The level is negatively influenced by turnover (log). Certificates also have a negative effect on innovative output for medium-sized firms.

table 18 Estimation results innovation output model, type-2 Tobit model

	All firms				*Small firms*				*Medium firms*			
	Probit part		*Ols part*		*Probit part*		*Ols part*		*Probit part*		*Ols part*	
	Coef	*T-value*	*Coef*	*T-value*	*Coef*	*T-value*	*Coef*	*T-value*	*Coef*	*T-value*	*Coef*	*T-value*
Constant	-0.39	-0.8	38.48**	2.1	-1.15	-1.6	64.21*	1.9	0.06	0.1	56.19***	3.1
Innovation intensity	0.00	1.2	0.48***	12.0	0.00	0.5	0.44***	7.9	0.03***	2.9	0.46***	6.5
Degree education	0.00	1.4	0.03	1.4	0.00	1.1	0.01	0.4	0.00	0.4	0.05	1.1
Courses financed by firm	-0.00	-1.4	-0.06**	-2.2	-0.00	-0.9	-0.05	-1.3	-0.00	-1.1	-0.05	-1.3
Nat. subs.	0.20*	1.7	3.35**	2.1	0.02	0.1	4.97*	1.7	0.25	1.6	1.23	0.7
Eur. subs.	-0.18	-1.0	-4.23	-1.6	0.13	0.4	-9.79*	-1.8	-0.41*	-1.7	-0.07	0.0
Cont. innovation	0.39***	3.6	5.75**	2.1	0.41***	2.8	5.17	1.2	0.42**	2.5	1.22	0.4
Innovation written down	0.05	0.5	1.44	0.9	-0.06	-0.5	1.14	0.5	0.32**	2.0	1.13	0.5
Certificate	-0.11	-1.4	-3.02***	-2.6	-0.13	-1.2	-1.65	-0.8	-0.05	-0.4	-3.19**	-2.5
Change in organiza-tion	0.23**	2.5	2.90**	2.0	0.27**	2.0	2.56	1.0	0.28**	2.0	1.28	0.8
Customer satisfaction	0.33***	3.4	0.87	0.5	0.38***	2.7	-1.39	-0.5	0.33**	2.3	0.77	0.5
Market research	0.06	0.6	0.11	0.1	-0.11	-0.8	-0.51	-0.2	0.23	1.4	0.64	0.4
Intermediate	-0.23**	-2.4	-0.90	-0.6	-0.31**	-2.2	0.94	0.3	-0.21	-1.4	0.03	0.0
Product innovation	0.61***	11.9	2.52	0.9	0.60***	8.6	-1.94	-0.5	0.66***	8.2	0.38	0.2
Process innovation	0.11	1.0	-2.72	-1.5	0.11	0.8	-4.56*	-1.7	0.05	0.3	0.11	0.0
Co-op other firms	0.15	1.6	0.26	0.2	0.08	0.6	0.08	0.0	0.23	1.6	-1.09	-0.7
Co-op research inst	-0.21*	-1.8	1.50	0.9	-0.09	-0.5	6.06*	1.8	-0.36**	-2.1	-0.03	0.0
Co-op universities	0.03	0.2	0.84	0.6	0.22	1.4	1.80	0.6	-0.10	-0.7	-1.19	-0.7
Log turnover	0.14**	2.0	-4.67***	-3.8	0.28***	2.6	-6.27**	-2.5	0.03	0.2	-4.05**	-2.2
Turnover growth	0.00	1.0	0.04***	3.8	0.00	1.1	0.04***	2.6	0.00	0.5	0.05***	3.1
Export growth	0.01	1.1	0.25***	3.1	0.00	0.2	0.24*	1.9	0.02	1.3	0.16	1.5
Profit development	0.03	0.7	0.38	0.5	0.12*	1.7	0.41	0.3	-0.08	-1.1	0.37	0.4
Dummy loss99	-0.28*	-1.7	5.96**	2.1	-0.09	-0.4	11.14***	2.6	-0.62**	-2.1	2.40	0.7
Dummy profit99	0.03	0.2	-0.04	0.0	0.08	0.5	1.73	0.6	-0.09	-0.4	-2.09	-0.9
Dummy industry	0.14	1.5	-0.42	-0.2	0.18	1.4	-1.26	-0.4	0.12	0.8	-0.98	-0.4
Dummy trade	0.17	1.6	1.09	0.5	0.27*	1.8	-0.67	-0.2	0.09	0.6	1.05	0.4
Dummy hotel, transport	0.08	0.5	6.63**	2.2	-0.15	-0.6	11.879*	1.9	0.23	1.0	3.75	1.2
Dummy services	0.08	0.8	1.28	0.6	0.19	1.3	1.38	0.4	-0.06	-0.4	-0.26	-0.1
Inverse mills ratio			31.66	1.0			-1.16	0.0			-20.75	-0.7
# Of firms	1.418		1.099		719		538		699		561	
R-sqrd			0.31				0.31				0.23	
McFadden R-sqrd	0.25				0.244				0.31			

$^{*}p$ <.10, $^{**}p$<.05, $^{***}p$<.01.

Source: EIM, 2002.

A striking result is the positive impact on innovative output of the event of a loss in 1999 for small firms. The size of the effect is very large. Small firms with losses could concern firms in the start-up phase, which invest heavily in innovative activities, resulting in modest innovative output, while turnover remains at a low level.

5.4 Determinants of firm performance

The last step in our analysis deals with the relationship between innovation and firm performance. We tested for four different performance measures: the growth in turnover, growth in employment, profit and productivity in 1999. We will only present the results of the growth in turnover (table 19) and employment (table 20). The regression for profit is not significant and the differences in productivity are only explained by the sector dummies. It is important to remark that although the R^2's for the presented equations are low for all regressions, the regressions are significant. This implies that turnover growth and employment growth are to a large extent explained by other aspects.

For all firms as well as small and medium-sized firms separately, the innovative output has a significant and positive effect on the turnover growth. The effect for small firms is stronger than for medium-sized firms.

table 19 Relationship innovation and turnover growth

	All SMEs		*Small firms*		*Medium firms*	
	Coefficient	*T-value*	*Coefficient*	*T-value*	*Coefficient*	*T-value*
Constant	26.83^{***}	3.15	35.80^{**}	2.39	19.91^{**}	2.55
Innovative output	0.40^{***}	6.73	0.46^{***}	5.27	0.20^{***}	2.88
Dummy industry	0.43	0.13	4.34	0.76	-2.18	-0.71
Dummy trade	0.41	0.11	2.87	0.47	-1.91	-0.56
Dummy hotel, transportation	5.45	0.94	8.79	0.82	3.82	0.76
Dummy services	9.13^{***}	2.64	10.61^{*}	1.85	5.73^{*}	1.67
# of firms	1857		999		858	
R^2	0.05		0.04		0.03	
F value	$F(5,1851) = 18.19^{***}$		$F(5,993) = 8.57^{***}$		$F(5,852) = 5.86^{***}$	

$^{*}p< .10$, $^{**}p<.05$, $^{***}p<.01$.
Source: EIM, 2002.

Employment growth is explained by innovative output as well as turnover growth. For medium-sized firms, the effects are larger. The employment growth of small firms is not explained by the innovative output.

table 20 Relationship innovation and employment growth

	All SMEs		Small firms		Medium firms	
	Coefficient	T-value	Coefficient	T-value	Coefficient	T-value
Constant	4.47**	2.48	0.57	0.37	5.82*	1.74
Innovative output	0.03**	2.20	0.00	0.69	0.09***	3.00
Turnover growth	0.02***	4.87	0.02***	5.51	0.06***	4.18
Dummy industry	-0.28	-0.39	0.07	0.11	-0.84	-0.64
Dummy trade	-0.27	-0.36	-0.04	-0.06	-0.56	-0.38
Dummy hotel, transportation	3.93***	3.21	-0.05	-0.04	5.94***	2.76
Dummy services	-0.19	-0.27	0.47	0.81	-0.58	-0.40
# of firms	1847		994		853	
R^2	0.03		0.04		0.05	
F value	F (6,1840) = 8.56***		F (6,987) = 6.64***		F (6,846) = 7.90***	

*p< .10, **p<.05, ***p<.01.
Source: EIM, 2002.

5.5 Conclusion

In this chapter, we have presented several econometric models to test the relationship between innovative input, innovative output and firm performance.
From the estimation results we can conclude that there is a clear distinction between small and medium-sized firms. For small firms, several process indicators are significant. In these variables, the size effect come to the fore, for instance, national subsidies are significant and European subsidies are not. Also the innovative intensity of small firms is significantly influenced by contacts with the intermediate organisation. The turnover has a negative effect on the innovative intensity of small firms. This implies that the larger the small firm, the less time is spent on innovation. This size effect disappears when only small firms with innovative output are included in the sample.

For medium-sized firms, the innovative intensity is only explained by continuous innovation. If only companies with innovative output are included, even this effect disappears. The innovation intensity is an important variable for explaining the innovative output, for small as well as for medium-sized firms. Most variables that are significantly explaining innovative output are corresponding between small end medium-sized firms. The most interesting difference is the negative effect of certificates on the innovative output of medium-sized firms. For small firms there is no significant effect.

Finally, the relationship between innovative output and firm performance is tested. Firm performance is measured by four different indicators: turnover growth, employment growth, profit and productivity. For only two indicators, significant effects are found, turnover growth and employment growth. Profit and productivity are not significantly influenced by innovative output. The explained variance of all firm-performance indicators is low, leaving a large share to be explained by other aspects. Also here there is a big difference between small and medium-sized firms. For small firms the innovative output has a much bigger impact on the turnover growth than for medium-sized firms.

For employment growth we see the opposite effect: for small firms innovative output does not influence the level of employment growth, for medium-sized firms there is a positive effect.

6 Conclusions

Conclusion and discussion

In this study, we investigated the relationship between innovation and firm performance with a special focus on small and medium-sized firms. Based on the literature review, the process approach to innovation was used as starting point. In this process approach, the innovation process is split in four stages. In the first stage, a firm has to decide to be active in innovation or not. Once a firm decides to be active, it must decide how much to invest in innovation, i.e. the input stage. The innovative input has to be transformed in innovative output, i.e the transformation or process stage. The last stage is the output stage, the actual innovation/innovative sales. This innovative output has to contribute to the firm performance, e.g. in terms of turnover, employment growth or profitability. To test these kinds of models, sophisticated estimation techniques are used in the literature. These techniques are also used in this study.

Before testing these models, we performed a first inspection of the data. The firms were assigned to one of the four identified groups of firms: output-oriented firms, all-round firms, process-oriented firms and laggards. Output-oriented firms and firms lagging behind have a relatively low turnover per employee and a relatively low employment growth. Striking is the relatively high profitability of the firms lagging behind. This might lead to the conclusion that innovation not necessarily contributes to more profit. This seems to be confirmed by the results of our own analysis: innovative output explains only four percent of the variance in firm performance (operationalised as turnover).

The following conclusions can be drawn from our empirical test. The innovative input is explained for small and medium-sized firms by different factors. The size effect becomes clear for the use of subsidies. Small firms use national subsidies, medium-sized firms use European subsidies. Small firms have more innovative input if they innovate in a continuous way. Also medium-sized firms have higher innovative input if they innovate in a continuous way. For small firms also performance market research, having contacts with an intermediate organization and cooperation with other firms and research institutes have a positive effect on the innovative input.
If we only look at firms with innovative sales in the last three years (i.e. firms that have been successful in the innovation process in the past), we get a somewhat different picture. For small firms national subsidies and continuous innovation remain important. Market research, contacts with the intermediate organization and cooperation with research institutes are not significant anymore. For medium-sized firms, only European subsidies and continuous innovation have a weak effect on the innovative input.

Based on these results, one may conclude that the national innovation policy has a positive effect on the level of innovative input of small firms. The use of national subsidies and contact with the (government-supported) intermediate organization has a significant and positive effect on the level of innovative input. Once small firms have innovative output, these variables do not have an effect anymore on the level of the innovative output. The absence of this effect may be explained by the fact that small firms that have innovative output are relatively homogeneous concerning these variables. As a result these variables cannot explain the level of innovative input anymore. The variables help to discriminate between firms having innovative output and firms not having innovative output. If the variables of the national innovation policy are studied in isolation, it appears that companies that use (national) subsidies or have contacts with the intermediare organization have higher innovative input and output.

Another interesting finding is that the level of innovative input of small firms with innovative output is not anymore influenced by the cooperation with other firms. Also this variable seems to help to discriminate between firms with innovative output and firms with no innovative output.

Furthermore, we found a negative relationship between firm size (measured in turnover) and innovative input. Export growth has a positive effect on innovative input. If the sample is split up in small and medium-sized firms, these relationships are only significant for small firms. This finding is in line with previous empirical research (Vossen and Nooteboom, 1996; Kleinknecht, 2000; Lööf, 2001). Our findings indicate that the negative relationship is especially relevant for small firms. If the firms are bigger and more homogeneous (in our research ten or more employees), the negative relationship disappears. A similar argument can be given for the positive relationship between export growth and innovative input.

The effects of different variables on the innovative output are tested with two different Tobit models. The decision to have innovative output is positively influenced by the continuity of the innovation efforts, changes in the organization, the measurement of customer satisfaction and the focus on product innovations. Strikingly, contacts with the intermediate organization have a negative effect on the decision to have innovative output. The effect disappears for medium-sized firms. This might indicate that contacts with the intermediate organization have a negative effect on the transformation process from innovative input to innovative output. On the other hand, firms may get in contact with the intermediate organization once there are not successful in transforming input into innovative output. It may take time before the contact with the intermediate organization results in innovative output.

The level of the innovative input has a strong positive effect on the innovative output. For all firms together, national subsidies, continuous innovation and changes in the organization all have a positive effect on the innovative output. Cources financed by the firm and certificates have a negative effect on the innovative output. It looks like that these aspects hamper the creativity and the flexibility of the employees resulting in a lower innovative output. For small and medium-sized firms separately, most of the effects disappear. Only the effect of the level of innovative input remains significant. Furthermore, certificates have a negative effect on the innovative output of medium-sized firms. Finally, turnover has a negative effect and turnover growth a positive effect on the innovative output.
Our results suggest that innovation contributes to the turnover and employee growth. The employment growth is also influenced by turnover growth. For small firms, the innovative output does not influence the level of the employee growth. The innovative output has no effect on the profitability and productivity of the firm.

To conclude, our research shows that the innovation process of small firms differs from medium-sized firms. Therefore, it is important to treat both groups differently. Our results furthermore suggest that the national innovation policy stimulates especially small firms to increase their innovative input. On the other hand, the innovation policy does not have a direct effect on the innovative output. This might ask for slight change in policy, focusing more on the transformation process from innovative input to innovative output. Stressing the importance of continuous innovation, measuring customer satisfaction and the importance of product innovation may lead to an increase of the number of firms that have innovative output. Once they have innovative output, the level of input is important. As stated before, policy on this aspect seems to be effective, at least for small firms.

Finally, innovation seems to have a positive effect on the turnover growth and employment growth of organizations, although the size of the effect is relatively small. We could not find an effect on the profitability of the firm or the productivity.

Suggestions for further research

Based on the results of our study, we can formulate some directions for further research.

In this study, we only used single equations. However, the relationship between innovation and firm performance can be characterised by different feedback loop or reversed causalities. In our model, we did not correct for these possible reversed causalities. Further research is encouraged to test these reversed causalities, for example by using simultaneous equation models. Also a real longitudinal research design with repeated measures might solve the problem.

In our model, we used a single indicator for innovative input (percentage dedicated time to innovation) and innovative output (innovative sales). However, innovative input and innovative output are multi-aspect concepts. Besides the time dedicated to innovation, also R&D expenditures, the education of the employees, newness of the machines, etc. influences the innovation input. The innovative output may also be captured by the number of patents, new and efficient processes, etc. Further research is encouraged to use these multi-aspects approach to the innovation process.

In our study, we did not find an effect of innovation on profitability and productivity. From a theoretical perspective one may expect a positive effect. For firms that do not invest in innovation one may expect that the profit will decrease over time. Therefore, new research may focus on the relationship between innovation and the development or persistency of the profitability.

Findings in this study suggest that size is important when studying innovation. In this study we only have information on SMEs. To study the differences between SMEs and large firms, further research is suggested to incorporate large firms in the sample as well.

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Annex I Correlation matrix

	Inn. intensity	*Inn. output*	*Nat. subs.*	*Eur. subs.*	*Cont. innovation*	*Innovation writ-ten down*	*Change in organization*	*Customer satisfaction*	*Market research*	*Inter-mediate*	*Product innovation*	*Process innovation*	*Co-op other firms*
Inn. intensity	1												
Inn. output	.407 **	1											
Nat. subs.	.086 **	.136 **	1										
Eur. subs.	.049 *	.050 *	.255 **	1									
Cont. innovation	.172 **	.253 **	.255 **	.105 **	1								
Innovation written down	.070 **	.097 **	.288 **	.135 **	.304 **	1							
Change in organization	-.034	.094 **	.149 **	.084 **	.229 **	.229 **	1						
Customer satisfaction	.001	.074 **	.071 **	.039 *	.125 **	.263 **	.122 **	1					
Market research	.120 **	.121 **	.200 **	.075 **	.216 **	.246 **	.165 **	.218 **	1				
Intermediate	.134 **	.141 **	.308 **	.155 **	.294 **	.220 **	.169 **	.005	.183 **	1			
Product innovation	.182 **	.298 **	.251 **	.104 **	.480 **	.274 **	.230 **	.156 **	.238 **	.252 **	1		
Process innovation	-.007	.050 *	.040 *	.041 *	.238 **	.152 **	.225 **	.095 **	.074 **	.041 *	.266 **	1	
Co-op other firms	.101 **	.117 **	.191 **	.093 **	.199 **	.232 **	.134 **	.146 **	.178 **	.132 **	.228 **	.074 **	1
Co-op research institutes	.072 **	.073 **	.313 **	.176 **	.152 **	.251 **	.118 **	.107 **	.215 **	.166 **	.168 **	.006	.275 **
Co-op universities	.045 *	.070 **	.236 **	.127 **	.168 **	.253 **	.143 **	.110 **	.196 **	.152 **	.123 **	.067 **	.246 **
Log turnover	-.250 **	-.100 **	.257 **	.105 **	.207 **	.332 **	.278 **	.162 **	.163 **	.041 *	.141 **	.248 **	.120 **
Turnover growth	.066 **	.178 **	.029	.037	.090 **	.053 **	.095 **	.027	.036	.120 **	.085 **	.072 **	.056 **
Export growth	.074 **	.106 **	.049 *	.027	.059 **	.053 **	.054 **	.009	.065 **	.036	.035	.030	.025
Profit development	-.003	.044	-.038	-.012	.006	-.043 *	.015	.000	-.032	-.033	.015	.045 *	-.030
Dummy industry	-.129 **	-.125 **	.164 **	.067 **	.022	.000	.040 *	-.009	-.021	.006	.026	.042 *	-.012
Dummy trade	-.004	.017	-.080 **	-.038 *	-.008	-.02	.013	-.013	.049 **	-.002	-.051 **	.004	-.010
Dummy hotel, transport	-.018	.012	-.059 **	-.028	-.023	-.001	-.018	.047 *	-.010	.001	-.045 *	.024	.010
Dummy services	.182 **	.162 **	-.051 **	-.023	.031	.013	-.043 *	.035	.037 *	.007	.090 **	-.046 *	.041 *
Dummy loss 99	.113 **	.077 **	035	-.003	.038 *	.028	.041 *	-.02	.028	.042 *	.020	-.006	.016
Dummy profit 99	-.137 **	-.049 *	.016	-.005	.015	.001	-.002	.011	-.008	.008	.002	.041 *	.022

	Co-op research institutes	Co-op universities	Log turnover	Turnover growth	Export growth	Profit development	Dummy industry	Dummy trade	Dummy hotel, transport	Dummy services	Dummy loss 99	Dummy profit 99
Inn. intensity												
Inn. output												
Nat. subs.												
Eur. subs.												
Cont. innovation												
Innovation written down												
Change in organization												
Customer satisfaction												
Market research												
Intermediate												
Product innovation												
Process innovation												
Co-op other firms												
Co-op research institutes	1											
Co-op universities	.340 **	1										
Log turnover	.215 **	.180 **	1									
Turnover growth	-.022	-.020	-.031	1								
Export growth	.062 **	.023	.016	.083 **	1							
Profit development	-.035	-.010	-.023	.071 **	.050 *	1						
Dummy industry	.088 **	.034	.182 **	-.074 **	.025	-.024	1					
Dummy trade	-.059 **	-.056 **	.071 **	-.032	.023	.017	-.428 **	1				
Dummy hotel, transport	-.038 *	-.044 *	.019	-.005	-.001	-.030	-.172 **	-.086 **	1			
Dummy services	-.036	.008	-.278 **	.129 **	-.034	.019	-.569 **	-.285 **	-.115 **	1		
Dummy loss 99	.021	.019	-.079 **	-.056 **	-.019	-.112 **	.052 **	-.011	.003	-.028	1	
Dummy profit 99	.025	.021	.143 **	.072 **	.016	.163 **	-.022	.029	-.024	-.014	-.452 **	1

*** Correlation is significant at the 0.01 level 2-tailed.*

** Correlation is significant at the 0.05 level 2-tailed.*

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